THE

JOURNAL OF GEOLOGY

FEBRUARY-MARCH, 1893.

AN HISTORICAL SKETCH OF THE LAKE SUPERIOR REGION TO CAMBRIAN TIME.[1]

(WITH PLATE I.)

THE ancient formations south of Lake Superior may be grouped into five great divisions: the Basement Complex, the Lower Huronian, the Upper Huronian, the Keweenawan, and the Lake Superior Sandstone. These five divisions are separated by unconformities of great magnitude, two of them at least being of the first order. According to the classification adopted by the United States Geological Survey, the Basement Complex is Archean; the Lower Huronian, Upper Huronian and Keweenawan constitute the Algonkian for this region; and the Lake Superior Sandstone is Cambrian.

The Basement Complex.—The characteristic rocks of the Basement Complex are (1) light colored granites and gneissoid granites, and (2) dark colored finely foliated or banded gneisses or schists. These are cut by various basic and acid intrusives, many of which are not different from eruptives

[1]In this very general article no attempt will be made to give references to the many authors from whom facts are taken. To give full credit for all information used would require citations from scores of papers. The writer gives a summary of the literature of the Lake Superior Region in Bulletin 86 of the U. S. Geol. Survey.

Many of the problems considered have no definite answers as yet. The aim of the article is to give a summary of the very limited knowledge available on a subject that has not before been considered, because the data were not at hand upon which to base any reliable conclusions.

VOL. I.—NO. 2.

found in the later series, with which they are doubtless in part continuous.

The granites and gneissoid granites are placed together, because between the two are constant gradations. If one speaks accurately and includes among granites only those rocks which are completely massive, the gneissoid granites include the greater part of the granitic rocks; for in large exposures it is usually possible to find some evidence of foliation. The granitoid areas are of greatly varying sizes, running from small patches to those many miles in diameter. When everywhere surrounded by the schistose division of the Basement Complex, they frequently have oval or ovoid forms. In nearing the outer border of the granitoid areas, the foliation often becomes more and more prominent, and near the edge of an area the rock frequently passes into a well laminated gneiss.

The schistose rocks include fine grained hornblende-gneisses, mica-gneisses, chlorite-gneisses, and various green schists, formerly supposed to be sedimentary, but now known to be greatly modified basic and acid igneous rocks. These schists have usually a dark green or black color, are strongly foliated, and the variations in strike and dip of this foliation, within small areas, is very great. Not infrequently the schistose rocks are traced by gradations into massive igneous rocks.

The contacts between the schistose division and the granitoid division of the Basement Complex are usually those of intrusion, the granitoid rocks being the later. In passing from a schistose to a granitoid area, small pegmatitic looking veins of the granite are first found. In going onward these veins become more numerous and, after a time, unmistakable dikes of granite appear, which multiply in number and size in approaching the granite area, until the granite is found in great bosses. Here we have perhaps a nearly equal quantity of schistose and granitoid rocks, and in this intermediate zone the schists may be found as a mass of blocks within the granite, sometimes at but small distances from their original positions, the whole having frequently a somewhat conglomeratic appearance. However, these pseudo-

conglomerates, so well described by Lawson, grade more or less rapidly on the one hand into the schists, and on the other into the solid gneissoid granite. The complete change may occur within a short distance, or it may take a mile or more.

The Basement Complex is then composed of intricately interlocking areas of granitoid rocks and schistose rocks. Moreover, all of these rocks are completely crystalline. None of them show any unmistakable evidence of having been derived from sedimentaries, but many can be traced with gradations into massive rocks, and therefore the greater proportion of them are igneous, if a completely massive granular structure be proof of such an origin.

The Basement Complex is the most widespread of any of the Lake Superior systems, and it doubtless runs under all later formations to a greater or lesser distance. That it is continuous under all such formations can not be asserted, for while it was once so, it is possible, perhaps even probable, that in places, as a consequence of sedimentation and folding, the Basement Complex has been so deeply buried, that fusion has locally resulted. It is even possible that such fused material is a partial source of the later volcanic eruptions.

Before the earliest sedimentary rocks were deposited, the Basement Complex was subjected to enormous orographic forces, which folded and sheared the rocks in a most intricate manner. Accompanying the great orographic movements, which undoubtedly occupied a vast period of time, were intrusions of various deep seated igneous rocks, and also doubtless their volcanic equivalents were extruded. Subsequent to, and during the orographic movements, atmospheric forces were at work. Erosion continued long after the mountain-making folding had ceased, and, for much of the Lake Superior region, reduced the Basement Complex nearly to a plain or base level. As evidence of this may be cited the fact that, at the end of the erosion interval, the Basement Complex, consisting of differing lithological materials, and therefore having a variable resisting power, did not vary in altitude more than a few hundred feet for long dis-

tances. Whether this denudation extended everywhere deep enough to remove all surface volcanic material, and to leave only deep seated igneous material, is undetermined. At the beginning of the Lower Huronian time, the Basement Complex was, in the Lake Superior region, a universal system.

The Lower Huronian.—After the forces of erosion had nearly exhausted themselves, there was the first advance of the sea over the Lake Superior region of which we have any evidence, as a result of which the Lower Huronian was deposited.

The well-known characteristic rocks of the Lower Huronian, are (1) conglomerates, quartzites, quartz-schists and mica-schists, (2) limestones, (3) various ferruginous schists, (4) basic and acid eruptives, which occur both as deep seated and as effusive rocks. The order given, with the exception of the eruptives, is the order of age from the base upward.

The inferior formation is usually a quartzite or a feldspathic quartzite. Where metamorphism has been severe it passes into a quartz-schist, mica-schist or gneiss. The lowest horizon of the formation is in places a coarse conglomerate, and this when metamorphosed may become a conglomerate-schist. This conglomerate is of two types, depending upon the character of the underlying formation, which is here granitic and there schistic. The limestone formation, when at its maximum, is of very considerable thickness. The limestone is magnesian and so very crystalline as to make the name marble appropriate. It frequently contains a considerable amount of chert. In places it may be divided into two horizons, one of which is nearly pure marble, and the other nearly pure chert. At other times the limestone becomes very siliceous by a mingling of fragmental quartz, while zones of wholly fragmental material may occur. These impure phases are often at the lower part of the limestones, where they may be considered as a transition from the underlying formation. The formation overlying the limestone is usually known as the iron-bearing member, since it contains all the ore bodies of the Lower Huronian. It has varied aspects, but the different varieties grade into one another both vertically and

laterally, so that when one becomes familiar with them, the rocks of the formation may invariably be recognized. Here are included hematitic and magnetitic schists, cherts, jaspers, ferruginous carbonates, and other forms. The formation always differs from the limestone in carrying a very considerable amount of iron, and it differs from the quartzite in being largely, and sometimes wholly, a chemical or organic sediment, rather than a mechanical one.

The three members of the Lower Huronian are not often seen in a single section. This may be due to lack of exposures, but in some cases is undoubtedly due to the absence of one or more of the formations themselves.

In the Lower Huronian, basic eruptive rocks are abundant, and locally cover considerable areas. Not infrequently acid eruptives also occur. These eruptives include both contemporaneous volcanics and subsequent intrusives. If the Keewatin of Lawson about Rainy Lake and the Lake of the Woods is Lower Huronian, great granitic masses have been intruded into this series northwest of Lake Superior.

Equivalent to the Lower Huronian series of the north shore of Lake Huron are placed the following iron-bearing districts: Lower Vermillion, Lower Marquette, Felch Mountain, in large part, Lower Menominee, the cherty limestone formation of the Penokee district; and probably the Kaministiquia series of Ontario, and the Black River Falls series of Wisconsin. Whether all of these detached basins were once connected by continuous sediments is unknown, but probably they were.

The fragmental material of the Lower Huronian was derived from the Basement Complex. This fragmental formation is usually thin. This doubtless means that the advance of the sea over the Lake Superior region was comparatively rapid. The directions from which the Lower Huronion sea entered, and the extent of its trangression, is at present unknown. By certain of the Canadian geologists it is held that the structural break which exists between the Basement Complex and the Lower Huronian, south of Lake Superior and north of Lake Huron, does not exist

in the region of Rainy Lake and Lake of the Woods, northwest of Lake Superior. If this conclusion be true, the sea did not advance as far as the Lake of the Woods, this district perhaps being above the ocean, and one of the sources of detritus throughout Lower Huronian time.

The extent of the Lower Huronian deposits is also uncertain. If the series of the districts above placed in the Lower Huronian, are correctly correlated, Lower Huronian basins occurred in various places over a great triangular area extending from Black River Falls in Wisconsin, to northeastern Minnesota, and thence east to the north shore of Lake Huron. Doubtless Lower Huronian rocks also occur in the great northern region of Canada, and they may have had a much wider original extent than this, but no data are now available to locate such a possible extension.

Of the original thickness of the Lower Huronian deposits we are also ignorant. The present thickness has not been determined south of Lake Superior, but according to Logan, on the north shore of Lake Huron, including the interstratified volcanics, the thickness is five thousand feet.

At the end of Lower Huronian time, the Lake Superior region was raised above the sea, folded, and subjected to erosion. The orographic movements of this time were very severe, closely crumpling in places the rocks of the Lower Huronian, and inducing in them in many places a schistose structure. In other localities, away from the axes of great disturbance, the Lower Huronian rocks were but gently tilted, as is shown by the small discordance in places between them and the succeeding series. In certain localities the areas of great disturbance are but a short distance from those of comparative quiet. The denudation was deep enough to wholly remove the entire series over wide areas, and to cut to unknown depths into the Basement Complex itself. As has been stated, the Lower Huronian has an estimated thickness of about one mile on the north shore of Lake Huron, and in different localities varies from this thickness to entire absence, depending mainly upon the differing deundation. This variabil-

ity may possibly be due in part to highlands of the Basement Complex, which were not covered by the Lower Huronian sea until the period was well advanced. Of the extent of the series at the end of the erosion preceding Upper Huronian deposition, little has been determined, since later erosions have undoubtedly removed large areas of the series, and therefore its present distribution is not a safe guide to its distribution at the close of the erosion interval referred to.

The Upper Huronian.—At the close of the long period of erosion which followed the Lower Huronian deposition, the water once more advanced upon the Lake Superior region, and the Upper Huronian series was deposited.

Lithologically this series consists of conglomerates, quartzites, graywackes, graywacke-slates, shales, mica-schists, ferruginous slates, cherts, jaspers, ferruginous schists and igneous rocks, including both lava flows and volcanic fragmentals, as well as basic and acid intrusives. The series, as a whole, is very much less crystalline than the Lower Huronian, although locally the shales and graywackes have been transformed into mica-schists, and even into gneisses.

The Upper Huronian immediately about Lake Superior is divisible into three formations, a lower slate, an iron-bearing formation, and an upper slate, the basis of separation being that of mechanical and non-mechanical detritus. The inferior formation is mainly a quartzose slate or shale, but locally it passes into a quartzite, while the basal horizon is frequently a conglomerate. The nature of this conglomerate varies greatly, depending upon the character of the underlying formation, which, in some areas, is the Basement Complex, and in others the Lower Huronian. In the first case the slates may rest upon the gneissoid granite, upon the schists, or upon the junction of the two. The basal conglomerate corresponds in its character, being a recomposed granite or granite-conglomerate, a recomposed schist or schist conglomerate, or finally a combination of the two.

When the lowest member of the Upper Huronian rests upon the Lower Huronian series, the underlying formation may be

any one of the three formations of the Lower Huronian. As a consequence the basal conglomerate may consist mainly of the fragments of any one of these formations, or of all of them together. Not infrequently detritus, derived from the Basement Complex, is mingled with that of Lower Huronian origin. However, as a consequence of the resistant character of the jaspery iron-bearing formation of the Lower Huronian and of mining operations, the discovered contacts are most frequently between the Upper Huronian and this iron-bearing formation. In the basal conglomerate or recomposed rock at these points, the characteristic fragments are chert, jasper, and other ferruginous materials, and it is locally so rich in iron as to bear ore-bodies. The uppermost horizon of the lower slate of the Upper Huronian in the Penokee district is a pure, persistent layer of quartzite. The central mass of the formation is a graywacke or graywacke-slate, passing in places into a shale or sandstone.

Above the lower slate is the iron-bearing member, consisting of various ferruginous rocks, including cherts, jaspers, magnetite-actinolite-schists, iron ores, and ferruginous carbonates. It has been shown that all these varieties have been mainly derived directly or indirectly by transformation from an original lean, iron-bearing carbonate, which was of chemical or organic origin, or a combination of both. Mingled with these non-mechanical sediments is a greater or lesser quantity of mechanical detritus.

Above the iron-bearing formation is the upper slate formation. This is mainly composed of shales frequently carbonaceous or graphitic, slates, graywackes and mica-schists, often garnetiferous and staurolitic. The mica-schists are usually toward the upper part of the formation. The stages of the transformation between these crystalline rocks and plainly fragmental detritus have been somewhat fully made out.

The lower slate formation is of variable thickness, but is usually less than a thousand feet. The iron-bearing formation is also of very variable thickness, its maximum being perhaps about the same as that of the lower slate, and from this it varies to disappearance, the horizon being usually represented, however, by

carbonaceous and ferruginous shales and slates. The upper slate formation includes the great mass of the Upper Huronian series. Its maximum thickness is more than ten thousand feet.

In certain areas, during Upper Huronian time, there was great volcanic activity, as a result of which, peculiar formations were piled up, wholly different from any of the ordinary members of the series. Also this volcanic activity greatly disturbed the regular succession, so that for each of the volcanic districts an independent succession exists, the sedimentary and volcanic formations being intimately interlaminated. The two areas which are best known are the Michigamme iron district north of Crystal Falls and the east end of the Penokee district. Similar volcanics also occur in the Marquette district. In the Michigamme iron district is an extensive area of greenstones, greenstone-conglomerates, agglomerates and surface lava flows, many of which are amygdaloidal. In the Penokee district the materials are almost identical. The typical succession for this district extends in unbroken order for fifty miles or more, but east of Sunday Lake this is suddenly disturbed by the appearance of the volcanics. The character of the rocks and their order soon becomes so different that if one were not able to traee the change from one into the other, there would be a great temptation to regard the part of the series bearing volcanics earlier than or later than the Penokee series proper. But the continuity of the two cannot be doubted. Thus this occurrence well illustrates that lithological character in pre-Cambrian, as in post-Cambrian time is no certain guide as to relative age. Finally, associated with the Lake Superior Upper Huronian rocks are many later intrusive dikes and interbedded sills, chiefly diabases, gabbros and diorites, but local granitic intrusives also occur, particularly in the Felch Mountain and Crystal Falls districts, and possibly also in the Menominee district.

The typical districts in which the Upper Huronian series can be best studied are the Penokee, Marquette, Mesabi and Animikie. Remote from the Lake Superior region proper, the rock series

which are correlated with the Upper Huronian have not the same successions of formations as in these districts. The Upper Huronian north of Lake Huron has a set of formations which can not be correllated with the formations above given; the same is true of other series to the south which are here placed. The position of these latter as a part of the Upper Huronian must not be considered as a question finally determined, but rather as representing the probability, from the weight of evidence at the present time. It can not be expected that in a great geological basin the same subordinate succession of formations will be everywhere found.

However, for the present, regarding all these series as Upper Huronian, this is the most widespread of the Lake Superior pre-Cambrian sedimentary series. It includes a great area, extending from the Sioux quartzites of Dakota on the southwest, to the Huronian rocks north of Lake Huron on the east, and thence far to the north, and from Lake Huron to the Animikie series of the National Boundary west of Lake Superior. Within this area are included the major portion of the Baraboo quartzites of Wisconsin; the major portion of the large area in the Upper Peninsula of Michigan, the eastern arms of which are the Menominee, Felch Mountain, and Marquette iron-bearing districts; the greater part of the Penokee-Gogebic iron-bearing series of Michigan and Wisconsin; the Chippewa quartzites of Wisconsin; St. Louis slates of Minnesota including the newly developed Mesabi range of Minnesota, and the Animikie series of Thunder Bay, Lake Superior and its westward extension. That most, and perhaps all of these areas were once connected, there can be no reasonable doubt.

This broad semicircular zone of Upper Huronian rocks, extending from the National Boundary west of Lake Superior through Ontario, Minnesota, Michigan and Wisconsin, to the north Channel of Lake Huron, and thence north to the east side of James Bay, suggests that the transgression of the sea was from the south and east, and that the source of the mechanical detritus is the great expanse of so-called Laurentian rocks west of Hudson

Bay and north of Lake Superior. How far the sea transgressed over this area, and whether it also advanced toward it from the north and west, is unknown. It is probable as the sea advanced from the south, that the great mass of fragmental detritus, making up the Baraboo and Sioux quartzites, was laid down before the sea had transgressed to what is now the north shore of Lake Superior, and thus would be explained the discrepancy in the parallelism of formation between the Sioux quartzites, Baraboo quartzites, etc., and the districts of Upper Huronian rocks adjacent to Lake Superior.

In this case the advancing ocean was perhaps making its progress by cutting a terrace quite as much as by subsidence. However, there is reason to believe that the area included within the west end of the Lake Superior Basin, *i. e.*, from the Animikie series to the Mesabi range, and thence to the Penokee series was submerged practically at the same time. For here we have three great formations of like character in identical order. The lowest formation, the quartzite and quartz-slate with conglomerates derived from the Basement Complex and the Lower Huronian, are the first deposit of the advancing sea. After this came a deepening of the water, when the calcareous and ferruginous formation, now constituting the iron-bearing member, was laid down. Then perhaps as a consequence of the upbuilding of this formation, came a shallowing of the water and the deposition of the great thickness of clayey sediments of the Upper Huronian. Since the last formation must have been deposited in shallow water, and yet is of great thickness, the bed of the ocean was probably subsiding during the remainder of Upper Huronian time.

At the end of the deposition of the Upper Huronian rocks, the Lake Superior region rose above the sea, and the atmospheric forces once more set to work. The orographic movement following the Upper Huronian, like that following the Lower Huronian, was locally intense, but in general the folding was of a gentle character. Along narrow axes the plications were so severe as to give the Upper Huronian rocks a foliated structure and com-

pletely crystalline schistose or gneissic character, but for the most part the changes in the Upper Huronian rocks are those of cementation and metasomatism. As with the Lower Huronian areas of intense plication, they are sometimes but short distances from those in which the rocks have been merely tilted.

How deep the Upper Huronian denudation went it is impossible to say. We only know that at a maximum, the Upper Huronian rocks are now 13,000 feet thick, and in certain other places are entirely absent, the higher members disappearing first and the lower members last. Thus the difference of the Upper Huronian denudation is measured by 13,000 feet. To this must be added the unknown thickness of the Upper Huronian rocks, which have been wholly swept away, and the thickness of the Lower Huronian and Basement Complex, which were cut at this time. The thickness represented by these three elements is unknown, but it is probably great.

Of the outer limits of the Upper Huronian transgression, we are as ignorant as of the preceding ones, but certain it is that it had an extent to the outer areas mentioned as belonging to this series. Beyond these limits no knowledge is available. The original extent to the east, south and west of the Upper Huronian will probably never be determined, since the ancient rocks are covered by the Cambrian and post-Cambrian sediments. Whether the transgression extended over the Great Northern area of Canada to the Paleozoic deposits will doubtless be ascertained when this vast region is studied in detail.

The Keweenawan.—Again a change of conditions occurred, and a great flood of basic volcanics, in beds of enormous thickness were poured out. Later these were followed by more thinly bedded volcanics. At about the same time a portion, at least, of the Lake Superior region became immersed in the sea, since in places the basement lavas of the Keweenawan are interstratified with sandstone and conglomerates.

The Keweenaw series is composed lithologically of gabbros, diabases, porphyrites, amygdaloids, felsites, quartz-porphyries, etc., and of sandstones and conglomerates. The basic and acid

rocks constituting the series are mainly surface flows. The gabbro flows are often of immense thickness. The diabase flows are usually much thinner, and frequently pass in their upper parts into porphyrites and amygdaloids. Many flows are porphyritic or amygdaloidal throughout. The beds of quartz-porphyry and felsite are abundant in certain districts, but usually have no great lateral extent, but while a single flow may be traced but a little way, frequently a group of flows of the same general character may have a great extent and thickness. But even the groups of flows cannot be regarded as general formations for the whole of the Lake Superior basin.

Since the number and thickness of the volcanic beds as well as the detritals vary greatly, the Keweenaw series as a whole is widely variable in different districts in its character and thickness. Structurally, Irving has divided the series into two parts, a lower division, in which eruptives are present, and an upper division, in which eruptives are absent. In any one section of the Keweenawan, at the lower part of the lower division, are generally found numerous volcanic flows, with few or no detrital beds. In passing toward the middle of the series the sandstones and conglomerates become more and more numerous and of greater thickness. Still higher the sandstones and conglomerates become predominant, and finally volcanic products disappear, the upper ten or fifteen thousand feet of the Keweenaw series being wholly composed of mechanical detritus. A given detrital bed varies from a mere seam of narrow local extent to thick beds of sandstone and conglomerate, one of which has been traced by Marvine for more than one hundred miles. The most general detrital formation is the upper sandstone and conglomerate.

The Keweenawan rocks extend about the entire area of the Lake Superior basin. They appear upon the east shore of Lake Superior, cover a large area of Keweenaw Point, northern Wisconsin, eastern and northeastern Minnesota, and a great area about Lake Nipigon. A similar set of volcanics, occupying a like stratigraphical position, is also known adjacent to Hudson Bay, and this may be a contemporaneous series.

The Keweenawan is the thickest of the series about Lake Superior, its maximum being estimated by Irving at the Montreal river to be fifty thousand feet. From this thickness it varies to nothing. This vast quantity of material does not, however, of necessity mark a period longer or perhaps even as long as the Lower Huronian or Upper Huronian, for the greater part of it is of igneous origin. The lava flows in their extent and thickness are to be compared with the great volcanic plateaux of the far West, rather than with local volcanoes such as Vesuvius, or the local volcanoes of the Upper Huronian and Lower Huronian. Associated with the lavas no volcanic fragmental material has been as yet discovered.

The source of the lavas of the Keweenawan is beyond the scope of this paper. It was, however, suggested that the fusion of a portion of the Basement Complex, and even Lower Huronian, may have in part produced the deep-seated magmas, the extrusion of which produced the Keweenawan lavas.

In large measure the sandstones and conglomerates derived their materials from the volcanics of the series, but a lesser quantity came from earlier series. This latter is particularly true of the great detrital formation constituting the topmost member of the Keweenawan. Partly because fragments derived from the felsites and porphyries are more resistant than those from the basic rocks, acid pebbles are relatively abundant in the conglomerates.

The fact that erosion was contemporaneous with eruption for much of Keweenawan time is to be noted. Certainly, when the period was well inaugurated, most of the Lake Superior basin was normally below the sea or near tide water. Many of the eruptions may have been sub-aqueous. Here and there volcanic masses of such magnitude were built up as to rise above the water, and upon such areas, the sea at the base, and the air and rain above, immediately began their course of destruction. The acid and more viscous lavas may have formed the more prominent elevations, and thus the attack was here more vigorous. This may partly explain the predominance of the acid pebbles in the conglomerates.

This great volcanic period was doubless one of unstable equilibrium, the lithosphere falling here and rising there. One of the final movements was the production of the Lake Superior synclinal. This synclinal movement affects not only the Keweenawan rocks, but the lower series, and in areas in which the unconformity between the Upper Huronian and the Keweenawan is not great, there is such a likeness in strike and dip of the two series as to suggest, at first, that the two are conformable. It is only as the contacts between them are followed for some distance, and the Keweenawan is seen to be now in contact with one member of the Upper Huronian, and now with another, that it is perceived that between the two there is an unconformity.

What proportion of the Keweenawan had accumulated before this Lake Superior synclinal began it is impossible to say. Possibly somewhere near the center of the Lake Superior basin were the larger foci, from which the great extrusions of lava occurred, and here a simultaneous sinking went on, such as is usual as a result of the upbuilding of a mountainous mass of volcanic material. This suggestion, if true, would also partly explain the apparent absence of volcanic fragmental material which naturally would accumulate near these foci.

Nowhere are the Keweenawan rocks so closely folded as to give them a schistose structure or a metamorphic character. Their induration is almost wholly a process of cementation.

The Cambrian Transgression.—At the close of Keweenawan deposition the Lake Superior region was again raised above the sea, and the pre-Cambrian erosion continued until the enormous thickness of Keweenawan deposits was wholly truncated. What must have been mighty mountains were reduced to mere stumps, or to base level. Following this denudation, the sea once more transgressed upon the land, and the horizontal Lake Superior sandstone was deposited. It now occupies many of the bays about Lake Superior. It once was much thicker, and perhaps covered all but the highest points of land. Certainly it or an overlying formation once was at least one thousand feet higher

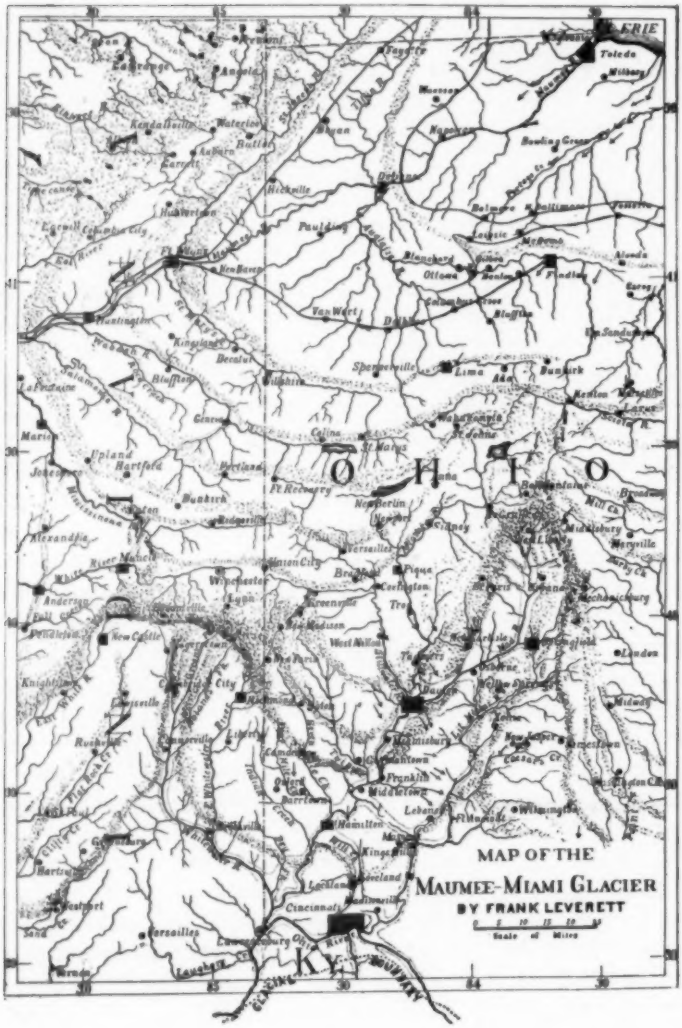
than the level of Lake Superior, but it has since been almost completely removed, so that it occurs only in patches within the depressions of the older rocks.

Since Cambrian time no important orographic movements nor outbursts of volcanic material have occurred in the Lake Superior region, consequently the rocks have received little subsequent alteration. To these facts is due the possibility of outlining the pre-Cambrian history of this area with greater fullness than has been done in areas in which later disturbances have obscured the early history.

C. R. VAN HISE.

THE GLACIAL SUCCESSION IN OHIO.

In Ohio, as in other portions of the Mississippi basin, clear and unmistakable evidence of discontinuity in the drift deposition has long been recognized. Whittlesey, Newberry and Orton were among the first to announce the occurrence of buried soils in the North American drift, and they each drew illustrations from Southwestern Ohio. A few years later Professor Chamberlin discovered evidences of late advances in which the outline of the ice-sheet was very different from that of the glacial boundary. He also observed that the aspect of the drift is much fresher than in the outlying earlier drift. He further noted the evidence of valley erosion of considerable amount effected in the interval between the formation of two moraines, or more accurately two sets of moraines, in Western Ohio, the oldest of which is much younger than the earliest drift sheet, as will be seen below. My own studies, carried on under the direction of Professor Chamberlin, have brought out more fully the nature and value of these and other intervals which exist in that region. No less than nine of the twelve criteria for discrimination between glacial epochs set forth by Professor Salisbury in the opening number of this Journal have been found, viz.: (1) Buried soils. (2) Buried fossiliferous silts. (3) Differential weathering. (4) Differential subaërial erosion. (5) Excavation of valleys between successive depositions of drift. (6) Changes in the course of ice-currents and in the outline of the ice margin. (7) Superposition of drift of different physical constitution. (8) Varying altitudes of the land. (9) Variations in vigor of ice action. Although the present state of knowledge of the Ohio drift is far from being as complete as one could desire, it seems profitable to review such evidence as throws light upon the value of the several intervals which mark the glacial succession in that state. In the western portion of


L. ERIE
O H I O
KY.
MAP OF THE
MAUMEE-MIAMI GLACIER
BY FRANK LEVERETT

EXPLANATION OF MAP.— This map was designed for another purpose, and hence includes only a portion of the district under discussion, though it represents the principal features herein discussed. Certain features, not discussed at this time, beach lines, eskers, esker troughs, etc., appear on the map.

The shaded portions of the map represent moraines, the shading being graduated to the strength of the moraine. Arrows indicate the position and bearing of striæ. Continuous lines are used to indicate the beaches of the Maumee basin and the south-western outlet of the lake which formed them. The second beach has not been fully traced, and is therefore incompletely represented. For the same reason the fourth and later beaches are not represented. Esker troughs are bounded by broken lines. The eskers which lie in them are indicated by continuous straight lines. The boundaries between upland and lowland tracts in southern Ohio are indicated by dotted lines. The glacial boundary, indicated by a broken line, appears for a short distance in the vicinity of Cincinnati.

the state there is a more complete and more easily deciphered record of the glacial succession than in the eastern portion, since the later advances there left a portion of the earlier drift uncovered. Our remarks will, therefore, relate chiefly to that district.

The full series of moraines formed by the Great Miami ice lobe, together with portions of the outer moraines of the adjoining East White River lobe on the west, and of the Scioto lobe on the east, are shown on the accompanying map. Outside the outer moraine of these lobes there is a glaciated district extending southward beyond the limits of the map in the main, its southern margin being the glacial boundary which lies fifteen to forty miles south from this moraine. That a long interval elapsed between the deposition of this outlying drift sheet and the formation of the outermost frontal moraine is shown below. Attention is called to it at this point, since it furnishes a convenient landmark in our discussion. The drift to the north of this moraine will be called, for convenience, by the general term, the later drift, while that to the south will be called the earlier drift. Both drifts have a somewhat complex history, and will be subdivided further on.

The earlier drift. For a few miles back from the glacial boundary in Northern Kentucky and in the hilly districts of

Highland, Adams and Brown counties, Ohio, there is a discontinuous or patchy deposit of drift, consisting in places only of scattering bowlders. In other places it consists of a clayey or sandy deposit, in which a few erratics are imbedded. In still others, notably at Split Rock and along Middle creek, west of Burlington, Kentucky, it consists of cemented coarse gravel. Only occasionally in the border portion is there a deposit of thoroughly commingled drift or typical till such as characterizes the thicker drift sheet immediately north. The attenuation seems due more largely to original deposition than to subsequent erosion.

Over the greater part of this earlier drift district back from the attenuated border one finds a nearly continuous deposit of till ranging from a few feet up to one hundred feet or more in thickness. It displays little or no aggregation in morainic knolls or ridges. The greatest thickness is found in filled-up valleys or in depressions, though the uplands in places carry as much as fifty feet of drift. Where less than twenty feet in thickness this drift sheet consists in the main of a yellow till. Where the drift has greater thickness a blue till is commonly found beneath the yellow. The blue till abounds in joints or irregular fissures filled with yellow or oxidized clay, a feature which is rare in the later drift sheet, and may, perhaps, constitute an important line of evidence as to the age. Both the yellow and the blue till are harder than those of the newer drift. The indurated character of this earliest drift sheet is apparently due to a partial cementation with lime, the drift being highly charged with a calcareous rock flour, a glacial grist.

The earlier drift seems to have been deposited in this district without great abrasion of the rock surface. No striæ have been found, though repeated search was made for them. (In districts further west striæ are occasionally found beneath the earlier drift). Between the blue till and the underlying rock there are frequent exposures of a few feet of earthy material having the appearance of residuary clay, or, if this be absent, a very rotten rock surface is usually found. In one village (Mt. Oreb) well

sections are reported to have passed through a black mucky clay, probably a preglacial soil, immediately beneath the blue till and a few feet above the rock surface. This feeble abrasion is thought to be due to lack of vigor in the ice-movement. The attenuated border is apparently due to the same lack of vigor and to a comparatively short occupancy of the region by the ice-sheet. The lack of vigor in this earlier invasion is in striking contrast with the vigor of the invasion which produced the outer moraine of the Miami and Scioto lobes, there being numerous exposures of striation in the district immediately north of that moraine, while the moraine itself bears evidence that the ice-sheet had great shoving power.

There is a possibility that this earlier drift sheet embraces two distinct periods of deposition. Evidence in support of this view is cited by Professor Orton in his report on Clermont county, Ohio (the county bordering the Ohio river just above Cincinnati), viz., that a buried soil and deposit of bog iron occur at the junction between the yellow and blue tills. From Professor Orton's account it would appear that no marked oxidation of the surface of the underlying blue till had occurred before the yellow till was deposited. We infer from this that the interval of deglaciation may have been comparatively brief, though it is possible that swampy conditions, such as prevail in the production of bog iron, prevented oxidation during a prolonged period. Inasmuch as Professor Orton is a careful observer and cautious writer, I do not feel free to question the evidence he cites, but my examinations in this district have not confirmed his evidence, so far as the location of the soil bed at this particular horizon is concerned. I have found testimony as to the occurrence of buried wood at or near this horizon, but not of soil beds. Possibly Professor Orton considers the occurrence of wood good evidence of an old land surface, but in view of the fact that wood may be incorporated in the drift as a part of the glacial debris I have not thought this a sure evidence. In the lists given in the Ohio reports, Dr. Newberry cites instances of wood to prove the existence of a "forest bed," and forest

bed and soil are terms which are used interchangeably in the Ohio Geological Reports. It ought also to be stated in this connection that a few miles to the north a buried soil occurs beneath the till, but it lies within the district covered by a later invasion of the ice, and the horizon is, I am convinced, above that of the one in question. There is also a soil above the yellow till of this earlier drift sheet which is buried by a silt deposit, as described below. I feel, therefore, that it is necessary to refer to different horizons the instances that have been reported from south-western Ohio.

Deglaciation interval with development of a soil attended by oxidation, leaching and erosion of the earlier drift sheet. Except where erosion has removed it a capping of silt several feet in thickness is found upon the surface of this till sheet. It is clearly of much later age than the till, being separated from it by a sufficient interval for the development of a soil, and for a large amount of oxidization and leaching and erosion. This silt is discussed below.

The soil which was developed on this till sheet does not commonly show a black color, though exposures of such a soil color are met with in all parts of the district outside the outer moraine. The evidence of a land surface is more generally found in the deep brown color, and weathering or soil-producing disintegration of the upper part of the till. The deep brown changes gradually below to the ordinary yellow color of oxidized till, but at top it terminates abruptly at the base of the overlying silt. The color of the silt being much lighter than that of this brown soil the contrast is very marked. The deep brown color extends usually to a depth of two feet or more, while discoloration extends to six or eight feet. The amount of discoloration is somewhat greater than is commonly found at the present surface of the newer drift. Repeated comparisons of the soil in the two districts lead to the conviction that this older drift sheet had been exposed as a land surface for a longer time before the silt was laid upon it than has the outer moraine of the newer drift up to the present date. The same conclusion is reached

upon comparing the amount of leaching in the two districts. In the earlier drift sheet it is rare to get a response with acid within six to eight feet of the surface, whereas in the newer drift the leaching has seldom been carried to so great a depth as six feet. It seems clear from the position and relations of this old surface that the leaching took place before its burial.

Concerning the amount of valley erosion accomplished in south-western Ohio during this interval no conclusion was reached. Sufficient time was not given to the study of the region to successfully eliminate the effects of post-glacial erosion and of erosion accomplished between the deposition of the silt and the invasion which produced the older moraine of the later drift. In eastern Indiana, however, there are exceptionally favorable conditions for determining the amount of erosion accomplished between the deposition of the earlier and later drift sheets, and it is believed that data of some importance can be furnished. Near the head waters of the Whitewater river there is a district covered by a thick deposit of drift. We may judge from wells made on interfluvial tracts that the level of the rock surface in that region is no higher than the valley bottoms of the several headwater tributaries of West Whitewater, and these valleys are, therefore, simply channels cut in the drift. The evidence all opposes the view that the ridges and valleys are in any way dependent upon preglacial erosion. The valleys along these headwater tributaries of the West Whitewater (Noland's fork, Green's fork, and West fork) are conspicuous for their size, their width being one-fourth to one-half mile or more and their depth sixty to one hundred feet. A similar broad valley is occupied by the headwaters of East Whitewater, though this stream has, since the later ice-invasion, cut a narrow gorge down into the rock strata.

This district of eroded drift was overridden by the western edge of the Miami and the eastern edge of the East White River lobe of the later incursion, but it so happens that the amount of drift deposited does not greatly conceal the outlines of these old valleys, the general thickness of the later drift sheet in this region

being not more than thirty to forty feet. The outer moraine of the East White River lobe, after following an upland tract west of the West Whitewater northward for some distance, descends, near Cambridge City, into the valley of the West fork of West Whitewater, and after crossing this valley rises near Hagerstown onto elevated upland. The outer moraine of the Miami lobe also, in crossing Noland's fork, south-east of Cambridge City, descends into and is developed in the valley as well as on the bordering ridges. That the valleys were formed previous to the deposition of this moraine, there can be no doubt, and being made entirely in the drift, as noted above, they show clearly that their excavation must be confined to the interval between the deposition of the earliest drift sheet and that of this moraine. The amount of erosion is several times as great as that accomplished by the streams that have traversed this valley since the moraine was laid down. The size of the streams which formed them constitutes an important factor in determining the time required in this excavation. That these interglacial streams were not much larger than those now traversing this region, seems probable from the fact that within a few miles north from the sources of the present streams, the general slope of the country becomes northward, so that drainage would naturally be in that direction, instead of southward along the Whitewater. The erosion here displayed seems, therefore, to indicate the lapse of a longer interval between the deposition of the earliest drift sheet and that of the outer moraine of the later drift, than the time that has elapsed since the formation of that moraine. How much of this interval preceded the silt deposition, it is difficult to determine, because the outer moraine has concealed the silt. Light upon this question should be obtained upon careful study of the lower portion of the Whitewater valley and of other valleys lying within the silt-covered district and outside the moraine, but this line of study has not yet been undertaken.

Depression accompanied by silt deposition. The silt which is found on the upland outside this moraine, has been discussed at

some length, in a recent paper.[1] It need, therefore, be but briefly touched upon here. It is there shown that it forms a practically continuous sheet over the southern portion of the glaciated district in Ohio and Indiana, and extends to an undetermined distance over the unglaciated districts of Ohio. It also appears on the uplands in Kentucky, south-west of Cincinnati, and may appear further east in that state. It has been found along the margin of the glaciated district in Ohio as far north-east as the vicinity of Newark, but has not been observed farther north and east.

The thickness of this silt decreases in passing southward, especially on the interfluvial tracts of south-western Ohio and south-eastern Indiana, a fact which seems to indicate that its source was from the north rather than from flooded conditions of the Ohio river. From evidence gathered in the upper Mississippi region, it is thought to be the correlative of a sheet of glacial drift not exposed to view in these states, or at least not yet discovered. Its thickness in the northern part of the district, next to the outer moraine of the newer drift, is four to six feet or more while on the borders of the Ohio river it scarcely exceeds three feet, and in places is two feet or less. Wherever examined it is found to be thoroughly leached. This fact is thought to be of importance in showing great age, especially on the theory of the glacial origin of the silt, since glacial silts, as well as till, in regions underlain as this region is by limestone, contain a large amount of calcareous material.

The amount of depression involved in this subsidence is difficult to determine. As yet such data as have been discovered bearing upon the altitude of the land, either previous to or during the depression, are not precise, though it seems probable that the altitude was several hundred feet lower at the maximum of depression than at the present time, while before the depression the drainage appears to have been good, and we may suppose that the altitude was not much lower than at the present time.

[1] "On the Significance of the White Clays of the Ohio Region." American Geologist, July, 1892.

Re-elevation of the land. Between the deposition of this silt and the formation of the outer moraine of the later drift, the altitude appears to have become about as great as at the present, since, as shown below, the gravels deposited at that time along valleys leading away from the ice margin bear witness of vigorous drainage.

Outer moraine of the later drift. Since the position of this moraine is indicated on the accompanying map, it need not be outlined. It should, however, be stated that this moraine is overridden by a later one a few miles east of Hillsboro, Ohio, and has not been recognized in the eastern part of the State. The moraine consists of a ridge of drift one to two miles or more in width, standing, as a rule, but twenty to forty feet above the outer border plain. Its surface is gently undulating, there being but a few sharp knolls or ridges, such as characterize the surface of a later series of moraines described below. It is composed mainly of till, though gravel deposits are not infrequent, either in the low knolls or in beds or pockets incorporated in the body of the drift.

Striæ are numerous in the district immediately north of this moraine, and since the usual bearing is toward the moraine and not toward the glacial boundary, it seems evident that they were produced at the time of the later invasion. Some striæ near Cambridge City, Indiana, appear to be out of harmony with the ice-movement of the later invasion, and may, therefore, be older.

The older drift was but partially removed by this later invasion, and it is frequently encountered in wells and exposed in bluffs of streams. It is harder and dryer than the newer drift. In a few places, notably at Marshall and Martinsville, in Highland county, and in the vicinity of Wilmington, in Clinton county, a black soil is found at the base of the newer drift. I have seen it only at Wilmington, but Prof. Orton, in his report on Highland county, calls attention to its occurrence at Marshall, and I was told by well diggers of its occurrence in Martinsville. In Wilmington it is exposed in a railway cutting near the public school building, in the west part of the village. It consists

of black muck, several inches in thickness, overlain by till, and underlain by a yellowish sandy clay. The exposure only extends a foot or so beneath the muck, hence but little is known as to the character at this point of the underlying drift sheet. Dr. Welch, of Wilmington, has found pieces of coniferous wood imbedded in the soil in this and other exposures in that vicinity. He has preserved one piece which shows beaver cuttings. He has also discovered seeds of various plants imbedded in the muck, some of which now flourish only in higher latitudes. The contents of this muck-bed seem, therefore, to indicate an interglacial climate less genial than the present.

In his report on Montgomery county, Ohio, Professor Orton described a buried peat-bed exposed in the bluff of Twin creek, near Germantown. This peat contains the berries and fine twigs of cedar. At the time of Professor Orton's visit, in 1869, the peat was exposed for a distance of forty rods, and had a thickness of twelve to twenty feet. It was underlain by a bed of gravel. At the time of my visit, in 1889, its exposed thickness above the creek bed was about eight feet. It would seem, therefore, that the peat deposit has a somewhat lower altitude where now exposed than where Professor Orton saw it. Professor G. F. Wright, who has also seen the peat-bed, has suggested (Bull. U. S. Geol. Survey, No. 58, pp. 96-97) that it occupies a large kettle-hole, and that the higher portions of the peat-bed were near the rim. This peat-bed is overlain to a depth of 90 to 100 feet by a fresh-looking drift, mainly till, and evidently of the newer drift series. This locality is north of a later moraine than the one under discussion. It is not known whether the peat was accumulated during an interval of deglaciation between the formation of that moraine and the later one, or at an earlier time. The later interval seems to have been sufficiently protracted for the accumulation of this amount of peat.

Several wells in the east part of Wilmington have passed through a fossiliferous silt between the newer till and an older drift-sheet at a depth of about thirty feet. A few minute gasteropod shells obtained from this silt by Dr. Welch await specific

determination. None of them exceed one-sixth of an inch in diameter. Professor Chamberlin reports having observed a bed containing molluscan shells between the newer and older till-sheets at Greensburg, Indiana. (See Third Annual Report U. S. Geol. Survey, p. 333). Positive evidence is wanting as to whether these fossiliferous silts are of the same age as the silts which cover the district outside the moraine, but they appear to have about the same horizon. No fossils have been found in the silts outside the moraine. It seems not improbable, however, that if originally present their exposed situation is such that the fossils may have been dissolved and removed by leaching.

In the case of streams leading southward from this region of newer drift, careful discrimination is necessary to decide the age of terraces. The coarse, gravelly terraces of the Little Miami valley are referred to the stage when the outer moraine was formed. This valley carried a larger volume of water at that time than in later stages of glaciation, because it was more favorably situated for receiving glacial waters. The Great Miami valley was apparently flooded as much during later stages as at this time, and its gravels are largely of the age of the later moraines. The Little Miami gravels are made up, in large part, of coarse material as far down as the mouth of the stream, pebbles two to four inches in diameter being common. The coarseness of the material testifies to a fair gradient, presumably as great as the present altitude of the country affords. The gravels rise to a height of but fifty to one hundred feet above the present stream, and are near the bottom of the valley trench, for the uplands bordering this stream stand 300 feet or more above its bed. The flood stages, though characterized by a much more vigorous drainage than that which obtained while the silt was being deposited on the bordering uplands, did not reach by nearly 200 feet the limit reached by the silt-depositing waters —a fact which seems to be capable of explanation only on the assumption of great orographic movements.

Deglaciation interval in the later drift series. In his reconnaissance of Western Ohio, some ten years ago, Professor Chamber-

lin observed decisive evidences of the lapse of a considerable interval between the formation of a moraine lying east of Mad river, near Urbana and Springfield, and the moraines on either side of it, the moraine on the east being one of the later Scioto moraines, while that on the west is a Miami moraine. This older moraine proves to be the outer moraine of the Miami lobe (see map). While this moraine was being formed the Miami lobe occupied the Mad river drainage area, and the waters from the melting ice-lobe were forced toward the south into the Little Miami valley, passing just east of Springfield. The course is well defined, there being a gravel plain leading south along the east side of this moraine. The altitude of this gravel plain is much greater than that of the immediate bluffs of Mad river valley, but is lower than the water-shed between the Mad river and the Scioto river system, just east of it. It consequently presents somewhat the appearance of a broad irrigating ditch, following the face of a slope at a considerable altitude above the stream. When the ice had retreated from the Mad river basin the drainage of the high country to the east of Mad river soon opened channels directly across this gravel plain and the moraine west of it down to the trough in which the river flows. Similar channels were formed by streams leading down to Mad river from the elevated country west of its basin, and a broad valley was opened along the axis of the trough. When a fresh advance of ice occurred the Miami lobe came nearly down to the Mad river valley from the west and covered the upper portion of the western tributaries. Its moraine, in crossing the interglacial valleys, descends into them, but only partially fills some of them, thus repeating the phenomena of the outer moraine, in the Whitewater valley, as noted above. Similarly, the Scioto lobe trespassed on some of the eastern tributaries of Mad river, and its moraine partially fills the interglacial valleys. It should, perhaps, be stated that these interglacial valleys do not follow preglacial troughs, but instead, have bluffs standing as high as the interfluvial portions of the slopes of the basin. Their excavation began with the retreat of the ice-sheet from the outer Miami

moraine lying east of Mad river. It is difficult to determine the precise amount of excavation accomplished in this interval, since the portions of the valley lying beneath or within the later moraine are partially filled, while the portions lying outside the moraines afforded avenues for the escape of glacial waters, and were probably much enlarged thereby. It seems safe, however, to state that an amount of excavation took place that would require some thousands of years with a drainage system of the size of the present Mad river system, and with a gradient such as the region now affords. It may be added that in regions further west, if our correlations are correct, there are found evidences of the same deglaciation interval, but their discussion does not fall within the scope of this paper.

Main morainic system of later drift. The moraine just referred to (in whose re-entrant angle the Mad river basin lies) belongs to the system mapped and described by Professor Chamberlin, in the Third Annual Report of the U. S. Geol. Survey, as the "Terminal Moraine of the Second Glacial Epoch." As shown by Professor Chamberlin this moraine lies near the glacial boundary in eastern Ohio and north-western Pennsylvania, but farther west it falls short many miles of reaching the glacial boundary. It is a complex system, "constituting a belt rather than a single moraine," there being in places not less than four distinct members. Nearly everywhere in the state it presents a sharply indented surface, a feature which, as suggested by Professor Chamberlin, appears to indicate forceful or vigorous action of the ice-sheet. Its peculiarly sharp contours and their diagnostic characters make it the most conspicuous and distinctive morainic belt in the state. Other moraines, newer as well as older than this morainic system, assume in places the form of smooth ridges or have but gently undulating surface, and hence are less conspicuous features even where they have as great bulk as the individual members of this system. In western Ohio one of the members of this system (the second one of the group) carries on its surface large numbers of crystalline bowlders of Canadian derivation and the remaining members are liberally

supplied. In this respect this morainic system contrasts with all other moraines of Ohio, and especially with the later moraines, there being but few bowlders on their surfaces. In eastern Ohio bowlders are a less conspicuous though not a rare feature. The cause of this unusual abundance of bowlders is an interesting problem and one perhaps not easily solved. It has been suggested by some one, I think it was Mr. McGee, that an unusual abundance of bowlders on the later drift sheets may be an indication that the ice invasion which brought them in was preceded by a long deglaciation interval in the gathering ground, and that the Canadian highlands were scoured afresh after the lapse of sufficient time for ledges to have been seamed and broken under atmospheric influence. The suggestion seems worthy of careful consideration.

The drainage from the ice-sheet was especially vigorous at this time throughout the entire width of the state and as far to the east and west as this morainic system has been identified. The altitude could not well have been less than at present, and may have been somewhat greater.

The later moraines. Between this morainic system and the western end of Lake Erie six more or less distinct moraines occur, which were probably formed in comparatively rapid succession. They each consist usually of a broad ridge one or two miles or more in width, and twenty-five to fifty feet in height. They are each sufficiently bulky to have determined to a large extent the courses of the main drainage lines of northern Ohio (see map) and yet they seldom present a sharply indented or conspicuously broken surface. The overwash aprons and terraces connected with them indicate less rapid discharge of waters than from the earlier moraines, and that too in certain parts of the belts where conditions were very favorable for rapid escape of waters as in the north part of the Scioto basin. It is thought from this feature as well as from the aspect of the morainic ridges themselves, that the ice-sheet had less vigor than when forming earlier moraines. That there was a decrease in altitude seems also highly probable. As noted above, surface bowlders

are of comparatively rare occurrence, being apparently no more plentiful than in the body of the drift. The aspect of this group of moraines is so very different from that of the group which lies outside it, that it is thought not improbable that they are the product of a distinct invasion. No decisive evidence of a long deglaciation interval separating the two groups has, however, been discovered.

Summary. From the facts above presented the following stages of the glacial period seem sustained:

1. A glacial stage during which the ice-sheet extended farther south in western Ohio than in any later stage. This stage will need subdivision in case a buried soil horizon in the midst of its deposits be well substantiated.

2. A long stage of deglaciation marked by development of soil and by attendant oxidation, leaching and erosion of the drift sheet.

3. A stage of silt deposition during which the highest points in south-western Ohio apparently became covered at flood stages. From evidence gathered elsewhere it seems probable that the silt deposition accompanied a glacial stage whose deposits are concealed in this region by later drift sheets.

4. A glacial stage, during which the outermost well-defined frontal moraine was formed. The drift of this stage is concealed in eastern Ohio by the later moraines. Preceding this stage is an interval during which the valleys became opened again to such depth that the main streams, at the time of this later ice invasion, flowed at levels 200 feet or more below the level of the upland silt.

5. A stage of deglaciation of considerable length as indicated by valley excavation.

6. A glacial stage characterized by sharply indented morainic ridges, thought to indicate vigorous action. The ice-sheet reached about to the glacial boundary in eastern Ohio, but fell short many miles of reaching the boundary farther west.

7. A glacial stage characterized by morainic ridges of smooth contour. This stage embraces the final disappearance of

the ice-sheet from Ohio. A deglaciation interval is believed to have preceded this stage, but as yet, decisive evidence in support of this view is not obtained.

We may now profitably review what is known concerning the altitude in each stage:

1. During the earliest advance little of value is known in this region. The scarcity, if not absence, of coarse overwash material seems to indicate feeble drainage and consequent low altitude. It is true that the Split rock and Middle creek conglomerate indicate powerful water action, but if formed as they appear to have been beneath the ice-sheet, they show little as to the altitude of the land.

2. During the period of deglaciation following the deposition of the earliest drift there appear, from the character of the changes effected, to have been fair drainage conditions. We may presume, therefore, that the altitude was not much lower than the present altitude of the region (800–1000 feet A. T.).

3. During the period of silt deposition there can be little doubt that the region stood several hundred feet lower than now.

4. During the formation of the outer moraine of the later drift there were apparently as good drainage conditions as are now afforded in the western Ohio region.

5. During the succeeding deglaciation interval the erosion effected indicates a fair altitude.

6. During the formation of the main morainic system the maximum of elevation was probably reached, there being an especially vigorous drainage at that time, not only in Ohio, but as far to the west as the moraine has been correlated.

7. During the formation of the later moraines there seems to have been a return to low altitude, and still later the Champlain submergence of the coast and St. Lawrence occurred. It is important to note that the Champlain submergence is separated from the submergence which produced the silts of southern Ohio by the periods of high altitude just mentioned, a succession of

periods during which all the Ohio moraines, no less than twelve in number, were being formed.

The decision as to the relative length of the intervals of deglaciation is obviously dependent upon data gathered from the entire glacial field, and should not be rendered in the light of what can be gathered from this limited region.

FRANK LEVERETT.

TRACES OF GLACIAL MAN IN OHIO.

TRENTON and the Delaware Valley no longer have exclusive claims to reputed evidences of glacial man. For a number of years reports have come from the West of finds of implements in ice-age drift. Miss Babbitt in Minnesota, Cresson in Indiana and Metz and Mills in Ohio, have in turn announced the discovery of specimens of these rare and precious mementos of antiquity. I have already, in papers published in THE JOURNAL OF GEOLOGY and in the *American Geologist*, raised questions as to the proper interpretation of the finds in Trenton and at Little Falls, Minnesota. A brief study of the Ohio finds may now be undertaken with a view of presenting and weighing such doubts as may have arisen with respect to the value of the evidence furnished by them. I have endeavored in this, as in the other cases, to keep well within the bounds of legitimate criticism, desiring to allow all that can be justly claimed for the evidence presented in support of the theory of a glacial paleolithic man in America. In dealing with this subject, however, I have found it necessary to keep in mind the fact that the evidence to be considered has been collected and presented by advocates of the paleolithic theory who have welcomed finds without critical scrutiny, and have reached and presented conclusions as much because they were in the line of the expected and desired, as because they were actually susceptible of demonstration. The advocates of the theory have naturally taken every opportunity to emphasize the importance of the evidence collected as viewed from their own standpoint. To insure correct final judgment it is necessary that other points of view be taken and that the evidence be subjected to every possible test. I shall confine myself to fields in which I have made personal and most careful observations. I do not desire to secure the acceptance as final of any particular view with respect to the history of early man in America. I am not intro-

ducing or advocating a theory but attempting to insure the non-acceptance of any theory, howsoever plausible, that is not supported by conclusive proofs. Others have undertaken to show how much proof Ohio has furnished in support of a particular hypothesis; they cannot now object to my attempting to show how insignificant this proof really is.

At the meeting of the American Association for the Advancement of Science in Washington, in 1891, much attention was paid to glacial geology, and one paper by Mr. Frank Leverett, of the Geological Survey, treated of the gravels of Loveland, Ohio, and of the finds of implements in them by Dr. C. L. Metz. Mr. Leverett was then about to return to Ohio and I resolved to accompany him to the Little Miami Valley with a view of making a brief preliminary study of the gravels and their contents. A week later Dr. Metz joined us at Loveland, and we proceeded at once to the great gravel pits just west of the village. Gravel was then being taken by the Baltimore & Ohio Railway Company from the south side of the road, two hundred yards beyond the bridge, but the old pit is a little farther on and on the north side of the road, the excavation running into the high terrace from the track at an oblique angle. The excavation is upward of two hundred yards long, and is from two hundred to three hundred feet wide, and has an average depth of perhaps twenty-five feet. The west wall had not been worked recently, and was reduced by erosion to a steep slope covered with vegetation. The curved wall of the east side was thirty or more feet high and very steep, affording an excellent exposure of the gravels; these consisted of very coarse material laid down in heavy irregular beds. At least one-fourth of the mass consisted of sub-angular or but imperfectly rounded slabs and flattish masses of limestone, which lay flat or with a slight inclination toward the river. The larger slabs, which were often as much as two feet or more across, projected like steps or shelves from the wall. The remainder of the deposit consisted of smaller rounded masses and bits of limestone; of masses, bowlders and pebbles of granitic rock constituting perhaps one-

twentieth of the deposit, and of gravel, sand and calcareous powder.

There were, in places, indications of rude lenticular bedding of these materials with a pretty uniform general inclination toward the channel of the river. The appearance of newness exhibited by these deposits was wonderful; the surfaces of the stones were smooth and clean, and many of the interspaces were open as if formed but yesterday. A closer examination showed, however, that this appearance of newness was partly due to the fact that the waters charged with calcareous matter penetrated the superficial beds, partially setting the constituent parts and in a measure sealing the apertures, thus preventing the complete settling and filling that otherwise would have taken place. The constitution and conditions were pretty uniform throughout the section, save at the top where there was a deposit from two to four feet deep of ferruginous sandy loam, containing some fragments, pebbles and bowlders of several varieties of stone.

After three visits, and the most careful but entirely fruitless search for relics of art from bottom to top of the gravel walls, I found myself wondering whether there had not been some mistake, whether the objects found were really tools, or whether the collector had not mistaken materials descended from the surface deposits for gravel in place. It is unfortunate that the statements of collectors in such cases, correct or incorrect, cannot readily be subjected to competent tests of verity; we must be content with hedging them about with all available restrictions in the way of negative evidence.

Having, during the first visit, examined the site at some length, we proceeded to the office of Dr. Metz, in Madisonville, and were shown two objects obtained from the pit at a depth of about twenty-five feet beneath the surface. The smaller of these, a dark flattish piece of cherty, slightly water-worn stone, was rudely flaked along one edge, but the evidence of design was not at all convincing, and it seems useless to place the specimen in evidence. The other object was apparently a work of art, exhibiting decided indications of design. It was found in

the main gravel pit about twenty-five feet from the surface, by Dr. Metz, who expresses his full belief that it was in place in the gravels when found. A third slightly flaked stone from the same locality and position had been forwarded to the Peabody Museum at Cambridge. On examining this specimen at a subsequent date I found that it has no features that can with certainty be described as artificial.

It is not from a desire to discredit the observations of Dr. Metz, who is a most reputable and more than usually capable observer, that I raise the question of the verity of these finds. It is essential, in a case where so much depends on the finding of a single specimen, that every observation relating to it should be placed upon record in such a way that, in the future, judgments as to the value of the evidence may not be based entirely upon the testimony of a single observer whose acquirements may be restricted or whose preconceived notions may give a very marked bias to his observations and deductions.

Referring to the Loveland site, it may be remarked in the first place that it seems improbable that man would have occupied an area overrun by torrents capable of transporting, and transporting almost exclusively, the coarse materials forming these deposits, and the chances of the preservation of artificial features of specimens brought by floods from the valley above are extremely slight.[1] Of course, if man existed here during the glacial period, he may have sought the raw material for his rude arts on the banks of this stream during the periods of of low water and may have thus left the refuse of his shaping operations at almost any point; but a single specimen cannot, considering possible errors of observation, be regarded as sufficient for the establishment of such a conclusion.

In the second place, I may mention the fact that on carefully examining the Loveland specimen, I found it partly covered with dark, well-compacted earth, resembling the soil of the surface of

[1] The edge of the continental ice sheet was, according to Mr. Leverett, only about eight miles distant when these gravels were formed, which makes the probability of finding implements here still slighter.

the terrace, rather than the light-colored, fine-grained calcareous powder characterizing the matrix, such as there is, of the gravel deposits. It seems to me that there is in this observation, made also by Mr. Leverett, and still subject to verification if the specimen has not yet been cleaned, sufficient ground for raising the question as to whether it is possible that Dr. Metz could have mistaken a surface mass, descended into the pit from above, for gravel in place. Dr. Metz, or any other observer not a professional student of geologic phenomena, especially of talus phenomena, involving materials subject to resetting after degradation, or to sliding *en masse*, could readily be excused for making a mistake of this kind. Lest this suspicion of error should seem unfounded or uncalled for, I have prepared two sections, Figs. 1 and 2, which illustrate some of the many dangers besetting the way of gravel searchers. In Fig. 1, an ordinary profile, resulting from the removal of gravels for railroad ballast, is shown. Deserted by the workmen for a day or a week, objects from the surface deposits, *A*, may have fallen into the pit resting at *B*. The sliding of the mass, *a b*, might cover them to the depth of several feet, *C*, Fig. 2, and the effects of disturbance upon the surface are soon obscured or obliterated by weathering. Suppose now that Dr. Metz, or any one else, should appear upon the scene as the fallen mass is removed and penetrated by workmen, and should witness the uncovering of art forms at *D*, twenty-five feet beneath the surface of the terrace. It is vain to hold that there is no danger of mistake in such a case; the chances of error are really very great, and a little slip like this in observation would falsify the chronology of human history in this valley to the extent of some thousands of years.

It may be remarked that the terraces of the Little Miami were for a long period occupied by mound-building tribes whose implements and refuse of manufacture are scattered everywhere, and it is entirely within the range of possibility that such a partially worked specimen as this should have been left by them in the surface loams on the site of this pit at Loveland.

As to the nature of the object itself, a number of questions

may be raised, and we are justified in making all possible inquiries. It is a pick-like object, some six inches long, and perhaps two inches thick toward the larger end. The head is rounded, as if intended to fit the hand, and there is even an appearance, deceptive, no doubt, as will appear further on, of abrasion by use. The sides are neatly flaked, the apparent result of blows by a hammer, many of which seem to have served only to batter the edges, while others appear to have removed a series of flakes extending along the shaft from the head to near the point. The smaller end of the object is worthy of especial notice; the point, which probably was originally sharply pyramidal, has been removed by an oblique fracture, leaving a clean, unworn surface. A portion of the surface adjacent to the truncated point has not been shaped by flaking, but retains the original minutely granular weathered surface, indicating that the stone before flaking or remodeling was already pointed. The object was therefore not used after the breaking of the point, as the unworn fracture shows, and the presence of the unaltered original surface adjacent to the present point would seem to prove that it never was subjected to use. The material appears to be a fine-grained, light-colored limestone, having a conchoidal fracture. It is soft and brittle, and is not likely to have been employed in making tools, and especially pick-like tools. This observation leads to an inquiry as to whether it is possible that the flaking could have been the result of natural agencies, such, for instance, as the crushing and abrading forces exerted by moving ice. Could a pointed bit or mass of brittle limestone have been so squeezed between moving impinging rocks as to remove these flakes and to produce the battered and rounded effect seen upon the edges and head, respectively, of this object without affecting the point, save to break it, and without breaking the shaft elsewhere? That natural forces do occasionally produce forms resembling those of art is well known, and that archæologists have at times been rash in accepting such as artificial cannot be denied.

To more fully inform myself upon this topic I made careful examinations of the contents of the moraine from which por-

tions, at least, of these gravels descended. I was somewhat surprised with the results, which proved so interesting and suggestive that they may well be referred to in this place. In a railroad cut recently made through morainal deposits near South Lebanon, about eight miles north of Loveland, I found numerous pieces of this brittle limestone, varying from minute bits to masses a foot or more in greatest dimension, showing traces of fracture and flaking resembling somewhat closely those of the implement or object found by Dr. Metz at Loveland. Indeed, some of these specimens are so well flaked that I would, under ordinary circumstances, not hesitate to call them artificial. In fact, all may be artificial, although the shapes are often eccentric, and the size, in cases, is greater than in any known flaked tool. It is a significant fact that nearly all the stones found in the deposit are covered with glacial striæ, and some of the conchoidal faces of the implement-like objects are scratched, through movements of the ice. It is true that man may have lived or hunted on or near the ice, and his tools or the refuse from their manufacture may have been taken up by the ice, passing afterwards into the moraine; but that they should enter the ice in numbers, and so become striated through its movements, is highly improbable. The Loveland specimen has, however, a more decidedly artificial character than any of these, and were its inclusion in the gravels fully verified, and were it not alone and practically unsupported by other finds, it could well be accepted as important evidence of glacial occupation by a stone-flaking people.

Besides the Loveland finds, Dr. Metz obtained a specimen of rudely flaked black chert from a cistern which he was sinking in Madisonville, Ohio. It was found at the surface of, or slightly imbedded in, gravel beneath a bed of silt eight feet thick.[1] Dr. Metz is a careful observer, and it is hard to believe that he would have permitted himself to be deceived although all must

[1] Putnam, F. W. Proc. Boston Soc. Nat. Hist., Vol. XXIII, p. 242.
Wright, G. F. Ice Age, pp. 530-532.
Leverett, Frank. Am. Geologist, March 1893, p. 187. According to Mr. Leverett it is not certain that these silts belong to the ice age, and if not, the find is no evidence of glacial man, whatever else it may signify.

admit the possibility of such deception. I have examined the specimen, now in the Peabody Museum, and find it to be identical in every essential feature with typical rejects of the modern blade-maker, lacking the least indication of specialization. It is not safe to call it an implement, no matter what its age, and to present it as evidence of paleolithic culture is little short of folly.

The discovery of a number of ancient hearths on the banks of Little Miami river was announced several years ago, and may be referred to in this place, since they were associated with deposits of ancient-appearing gravel. Professor Putnam gives the following information in regard to them: An exploring party "discovered five ancient hearths half a mile down the river from the Turner group of earthworks. These hearths were exposed by the river cutting away its bank. The lowest of the five . . . is thirteen feet below the surface of the bottom land, and rests upon a layer of gravel seven inches thick, upon which rest ten feet of alluvial deposit. This is by far the lowest and most ancient of the many hearths which from time to time have been exposed by the action of the river, as first noticed several years ago by Dr. C. L. Metz, who has examined a number of these ancient fire-places, and on one found fragments of pottery, which he sent to the Museum last year. These hearths are made of small boulders, in each case covering an area of several square feet. These stones are burnt, and many are splintered by heat. Upon the stones forming this oldest hearth was a considerable quantity of ashes and charcoal, but no other evidence of the work of man. These hearths furnish evidence of the occupation of the bottom land at different intervals during the formation of this deep deposit, filling the valley for miles in extent. That in this lowest hearth we have a considerable antiquity is self-evident; but how long after the formation of the glacial moraine, from which the gravel overlying it was derived, will only be determined by a careful study of the geology of the whole valley.[1]

[1] Putnam, F. W., 23d and 24th Annual Reports of Peabody Museum, p. 92.

In 1891 I visited this site with Mr. Frank Leverett. Traces of the fire-marked stones were found, but the waters had removed the hearths previously observed. A critical examination of the sedimentary deposits leaves the impression that they are quite modern. The upper surface is but little above the present flood plain, and has the appearance of a modern alluvial deposit of black, loamy earth, including thin irregular layers of fine gravels. I see no reason, considering the facility of mutation characterizing such deposits, why the hearths may not have belonged to the occupants of the site of the noted Turner group of mounds near by. It is seen from Professor Putnam's report that there were many hearths in and beneath these works. "An examination was also made of the surrounding embankment of the work, and much to our surprise portions of it were found to cover large areas of burnt stones. Several of these old fireplaces were explored inch by inch with the trowel, and in the ashes and among the charcoal were found numerous pieces of the bones of various animals, many potsherds, flint chips, broken and perfect implements, ornaments of several kinds, pieces of mica, etc., all similar to what has been found in previous years at other places in this interesting group of earthworks."[1] It may, I believe, be taken for granted that these hearths, notwithstanding their intimate relations with deposits of gravel, will never form any part of the evidence arrayed in support of an ice-age man or a paleolithic culture.

Another discovery, to which much attention has been given on account of its supposed bearing upon the paleolithic question, was made in 1889. Mr. W. C. Mills, of Newcomerstown, Tuscarawas county, Ohio, found a single specimen of chipped flint in an exposure of glacial gravel in that place. The specimen fell into the hands of Professor G. F. Wright, by whom it has been widely exhibited and published. A cut of it appeared in his "Man and the Glacial Period," from which work a brief extract may be given in this place. He states that Mr. Mills found this "finely shaped flint implement sixteen feet below the surface of the

[1] Putnam, F. W., 23d and 24th Annual Reports Peabody Museum, p. 94.

terrace of glacial gravel which lines the margin of the Tuscarawas valley. Mr. Mills was not aware of the importance of this discovery until meeting with me some months later, when he described the situation to me, and soon after sent the implement for examination. In company with Judge C. C. Baldwin, President of the Western Reserve Historical Society, and several others, a visit was made to Mr. Mills, and we carefully examined the gravel-pit in which the implement occurred, and collected evidence which was abundant to corroborate all his statements. The implement in question is made from a peculiar flint which is found in the Lower Mercer limestone, of which there are outcrops a few miles distant; and it resembles in so many ways the typical implements found by Boucher de Perthes, at Abbeville, that, except for the difference in the material from which it is made, it would be impossible to distinguish it from them. The similarity of pattern is too minute to have originated except from imitation."[1]

In another place Dr. Wright gives a statement of Mr. Mills in regard to the specimen, from which I quote the following additional details: "While examining the different strata of the gravel, I found the specimen that you have before you fifteen feet from the surface of the terrace. The bank was almost perpendicular at this time, exposing a front of about twenty feet. The small part of the bank was in place in the side of the terrace, until I struck it with my walking-cane, when a space of about six feet in length by two feet in height tumbled down, exposing to view the specimen. At first I recognized the peculiar shape and glossy appearance of the specimen, such as were characteristic of paleolithic specimens described to me by Professor Edward Orton, while I was a student at the Ohio State University."[2] Mr. Mills has, I believe, published nothing save through Professor Wright, and we must therefore take the above as the authoritative statements of the finding. A re-statement embodying additional minor details and placing the evidence fully and

[1] Wright, G. F. "Man and the Glacial Period," p. 251.

[2] Wright, G. F. Report of Western Reserve Historical Society, Dec. 12, 1890.

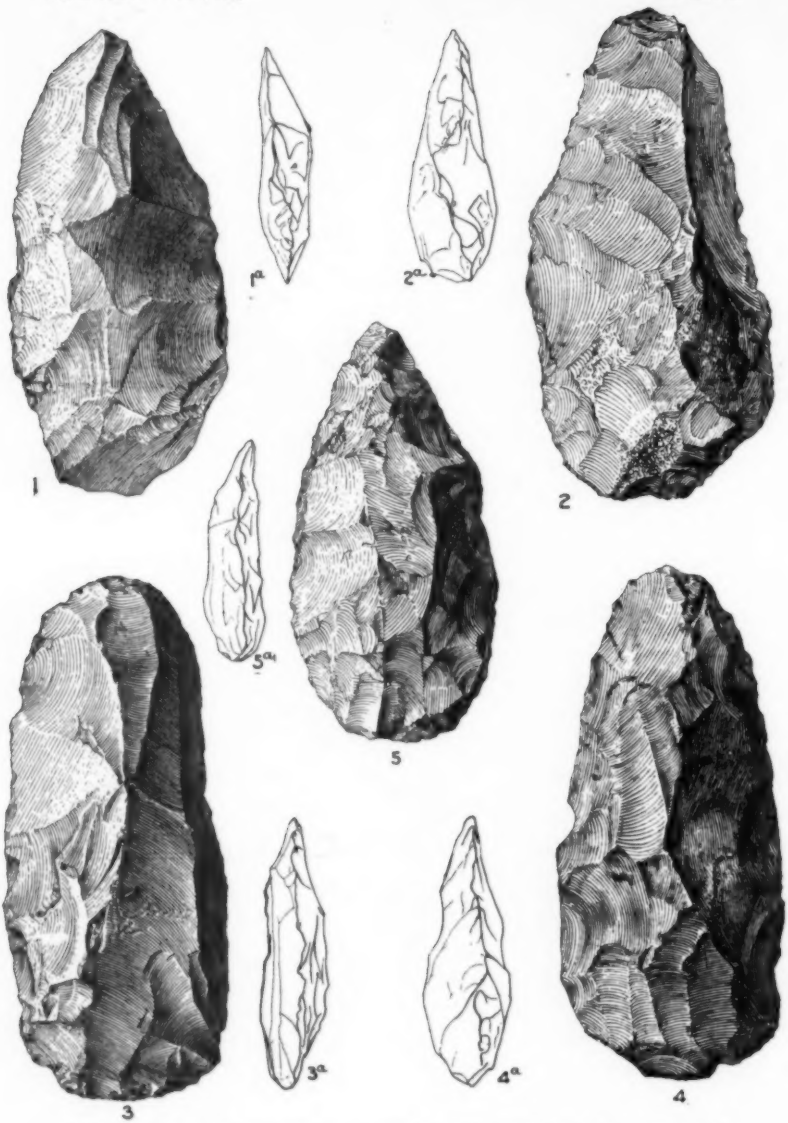


Plate illustrating the Newcomerstown "paleolith," copied with all possible care from the cut in "Man and the Glacial Period," and four ordinary rejects of the blade-maker, the latter obtained in three cases from modern flint shops in the same region, and in the fourth case directly traceable to the same shops. The separation of the "implement" of glacial age and paleolithic type from the modern rejects is left to the reader. Three-fourths actual size; the profiles on a still smaller scale.

finally upon record, an excellent thing to do, appeared in *Science* for February 3, 1893.

The question may now be raised as to the value to be attached to this find, since the observation is one upon which much is made to depend. In September, 1892, I visited Newcomerstown and examined the site of the discovery of this interesting object, which is shown in the accompanying plate. The town is built along the margin and on the slopes of a glacial terrace, formed about the end of a spur of the hills which projects into the valley on the north side of the Tuscarawas. The exposures of the gravels in the railway ballast pit are excellent, showing them to be ordinary irregularly bedded deposits of sand and gravel. It is a sufficiently promising place for the recovery of such implements or objects as the gravels may happen to contain. The formations are very loosely bedded, and it takes but a short time after the desertion of the site by workmen, especially if the weather is wet, to cover the exposures with talus. Large masses are liable to fall, carrying with them all objects resting upon and near the surface. A collector not on his guard, or not appreciating the nature or significance of finds, might readily, when afterwards questioned about the matter, give a faulty diagnosis of the conditions of discovery. The case in hand is one in which double assurance of verity is called for, yet it is one in which uncertainty resulting from the lack of experience and possible, I may say probable, carelessness of the collector is augmented by the treachery of the gravels. This uncertainty is again emphasized by the discovery, made at the time of my visit, that this terrace is probably an old Indian village site, and certainly a shop site where flint was flaked, many rejects and flakes occurring upon the very brink of the pit. Of course I found no duplicate of the specimen in question, for duplicates are *raræ aves;* but I saw enough to convince me of the danger of hastily and unqualifiedly making use of the observation made by Mr. Mills, especially since the material of which this object is made occurs in the neighborhood, and must have been used by the Indians inhabiting this site.

There is no doubt that this specimen suggests, perhaps more decidedly than any other American so-called gravel implement thus far collected, a resemblance to one of the well-known European types of implements. This is noted by Professor Wright, and may be regarded by many as a point worthy of attention. We must, however, look with extreme caution upon deductions drawn from or depending upon analogies of form. Close analogies of form between Indian rejects and some varieties of European paleolithic objects are too common to permit the attachment of much value to this feature of this or any other similar find. The remark of Professor Wright quoted above, that "the similarity of pattern is too minute to have originated except from imitation," is rather a novel statement, since no specimen of its type has been reported from the American gravels, and the Newcomerstown man could hardly have been familiar with European forms. The only available models would appear to be the Indian rejects of the valley of the Tuscarawas.

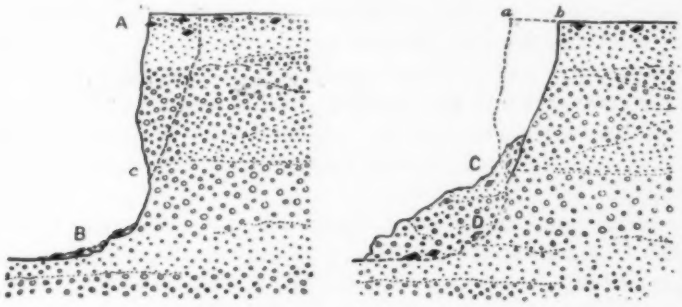
As to the surface polish, that is a common feature of the Ohio flints, and I have before me during this writing a tray of quarry rejects that have the same glazed effect. This is a characteristic of the stone, and has no bearing upon questions of age or use or culture, and must be considered as without significance in these connections.

Professor Wright is entirely satisfied with the results of his efforts to corroborate the statements of the collector. He has examined and reëxamined Mr. Mills, receiving every assurance of the verity of the find, but after all he really secures no additional assurance and can receive no fully satisfactory assurance that Mr. Mills was not in error. Professor Wright has visited and photographed the site and will speedily prepare a plate for publication,[1] for just what purpose, however, it is rather hard to see, since the nature of the gravels is not disputed, and a volume of photographs will not give additional weight to the proofs. A photograph made of the tree after the bird has flown will not help in determining the bird. No more will observations on Mr.

[1] Wright, G. F., Science, February 3, 1893.

Mills' moral character, his education or business reputation, diminish the danger of error. The specimen may not have been found in place notwithstanding all possible verification, and it may be a reject notwithstanding its resemblance to foreign types, and Professor Wright may be wrong in urging his conclusions upon the public, notwithstanding his painstaking efforts to secure all possible affirmative testimony.

It is nowhere stated that Mr. Mills actually picked the specimen out of the gravels; it was probably loose when he dis-



Figs. 1 and 2. Sections of wall of gravel-pit showing redistribution of surface objects by sliding masses. The dark figures represent objects of art.

covered it, but even if he could say that it was fixed in the gravel mass, the necessity of questioning the find would still exist. All the authentication Professor Wright can possibly secure will not enable him to determine whether Mr. Mills struck with his walking stick a small mass of the gravel in place at a depth of sixteen feet, or whether he was dealing with a mass which had slid with its inclusions of modern relics from the surface to a depth of sixteen feet, as indicated at C, Fig. 2. The object *may have been* in place, but can we afford to decide momentous questions upon the evidence furnished by a single specimen obtained under the conditions existing in this case, and by a collector who for months after the finding "was not aware of the importance" of the discovery?

At Warsaw, in Coshocton county, fifty miles west of Newcomerstown I visited an exposure of gravels in a railway cutting, the conditions being almost identical with those at Newcomerstown. The terrace, as in the other case, has been occupied by Indian flint workers, and being in the proximity of extensive flint quarries, there is much refuse of manufacture. I gathered a peck of turtle-backs and rude objects of paleolithic types from the level ground above, and in the wall of the gravel pit found several pieces, descended from the surface, that would be freely admitted into the paleolithic family by its sponsors. Work in the excavation had ceased several months before, and the face of the bluff, nearly thirty feet high and two hundred yards long, was well veneered more or less deeply with talus deposits, through which in places and especially near the top, the normal gravels could be seen. The redistributed deposits along the base of the steep slope were well reset, and from these I obtained a number of flaked flints; several of which were firmly imbedded, and two of them were removed from the gravel with some difficulty and with the aid of a pick, one twenty-five and the other twenty-seven feet beneath the surface of the terrace. The latter specimen is shown in the accompanying plate.

In studying this section at Warsaw I was led to realize the folly of hastily using inexpert evidence regarding the finding of relics of art in gravels. In a case like this even the experienced scientific observer, whose attention had not been definitely called to the nature and far reaching significance of such finds, might from a casual observation have recorded the recovery of one or more of these objects from the gravels. The danger would be greatly increased if the observer were only a relic hunter, or if he were convinced that the gravels at any depth might be expected to contain such objects. These specimens were in the gravels, firmly imbedded, and to all appearances this particular portion of the deposit was in a normal condition. Any one could here have dislodged a portion of the mass with his walking-stick, with fair prospect of finding a flaked stone of paleolithic type. I doubt very much if we are justified in using the casual obser-

vation of an inexpert collector at all in questions where there is no other well-established body of evidence with which to associate it. The function of such data does not extend legitimately beyond the confirming of testimony already well verified.

I present in the accompanying plate examples of the finds from the gravel talus and from the shops above. They correspond very closely in material and appearance with the Newcomerstown specimen, as will be apparent from an examination of the plate. The figures are presented without identification in order that the student may, by an effort to distinguish them, convince himself of the similarity of the supposed paleolith to the quarry-shop rejects of the region. I am not satisfied with the drawing of the former specimen which is a copy, the best that could be made, of the cut published in "Man and the Glacial Period." I desired to have a new drawing direct from the specimens, but a request looking to that end, made to Professor Wright, met with no response.

The four quarry-shop failures here shown are not rare finds with unusually implement-like features. They are everyday rejects, and four hundred could be presented as readily as four.

Summing up the evidence of gravel man in Ohio, assembling all of the finds of several earnest workers these many years—the fulfillment of Professor Wright's prophecy—we have to consider three specimens only. The finding of these objects seems ordinarily well attested, and there is not the least hint of deception or partial withholding of details of discovery. The specimen found by Dr. Metz in his cistern was eight feet deep, and on, or in, the surface of the gravel bed beneath eight feet of silt that may or may not be glacial. Eight feet is not a great depth, however, and we are justified, so long as the specimen stands alone, in expressing our fears that it might, through some unsuspected disturbance of the soil, artificial or natural, have been introduced or covered up to this depth at some date in the long period separating the ice age from the present. A number of agencies known to disturb the soil to considerable depths, are referred to in my paper on early man in Minnesota, in the April

number of *The American Geologist*, and Mr. Frank Leverett, in the March number of that journal, dwells at some length upon this subject. In response to an inquiry, I received the following note from Dr. C. Hart Merriam, the naturalist, on the burrowing of native animals:

"In reply to your inquiry respecting the depth to which our burrowing mammals penetrate, I regret to say that precise information on the subject is somewhat meager. A number of species, such as our woodchucks or marmots, skunks, foxes, coyotes, badgers and prairie dogs live in burrows of greater or less depth which they construct for themselves. In a few instances these burrows are known to extend to a depth of eight feet or more. One of the gophers is said to dig a spiral well fifteen feet deep. Badgers and prairie dogs are notorious diggers, making vast numbers of holes and bringing up immense quantities of material from unknown depths. Their burrows, moreover, are usually very steep, so that a stone or other object falling into one would descend to a considerable distance before being intercepted. Badgers and coyotes make very large holes, though small in comparison with those of the large wolf, which was formerly abundant throughout the Mississippi Valley; the burrows of the latter animal are of sufficient size to readily admit the body of a small boy."

The Loveland specimen was recovered at a great depth beneath the surface but we are bound to raise the queries, Is it an implement? Was it in place; and what is the meaning of the dark soil found on its surface? Of the Newcomerstown specimen it may be said that the collector had little knowledge of the nature of the gravels and of the treacherous character of talus deposits, or of the importance or peculiar bearing of the find. There is, therefore, a most serious possibility of error. There is a decided chance that errors of observation may have crept in in all the cases.

And what is the story of the specimens themselves? The Madisonville object is to all appearances an ordinary reject of the flint-blade maker. It can be practically duplicated upon

almost any quarry-shop site. The pick-like object from Loveland is somewhat unique, and thus has a certain interest of its own, independent of the manner of its finding. At best, however, it was probably not a finished implement at all and there is strong evidence that it has never been used. It may not have more than a remote resemblance to any tool ever employed by the occupants of the valley. The Newcomerstown object appears to have a marked resemblance to certain foreign implements, but the Tuscarawas valley flint-shops furnish many other specimens whose analogies are nearly if not quite as close.

These specimens constitute the Ohio evidence. There is nothing more, for it would be a great mistake to present surface finds as "paleoliths" or as gravel art, no matter how close their resemblance to these or to European forms. It is safest to assign all to the historic Indian save those obtained and proved to have been obtained from the gravels in place.

These three specimens furnish the most satisfactory proofs, so far collected, that a glacial, paleolithic man inhabited the Ohio valley, and upon the evidence of these three slightly shaped stones, obtained from isolated localities, it has been proposed to carry the history of man back some thousands of years farther than can be done by any other means yet discovered.

No careful student will venture to say that the evidence furnished by the three specimens is satisfactory and conclusive. The finds are not demonstrably implements but have the characteristics rather of rejects of manufacture. Their employment as evidence of a *paleolithic stage of culture* serves only to emphasize the utter inadequacy of the available proofs on that point.

Considering the meagre and unsafe nature of these proofs, there seems little doubt that a *glacial man* for the Ohio valley has been somewhat prematurely announced and unduly paraded.

W. H. Holmes.

THE VOLCANIC ROCKS OF THE ANDES.

THROUGH the excellent work of Dr. Richard Küch,[1] who has recently published the results of his investigation of the rocks collected by Reiss and Stübel in Colombia, we are put in possession of some important conclusions regarding the character of all the volcanic lavas of the South American Andes. Most of these conclusions are pointed out by Dr. Küch in the work cited; to these the present writer wishes to add a few not heretofore noted.

In order to appreciate the value of Küch's work, it should be observed that it was carried on upon the very extensive material collected by Reiss and Stübel during a prolonged exploration of the high mountainous regions of South America, in which they visited Colombia, Ecuador, Bolivia, Peru and Chili and brought away with them 18,000 specimens. In some places as many as 800 were collected, in others much fewer; for, as Reiss observes in the introduction to the volume upon Colombia, many of the mountains are well nigh inaccessible, their bases being covered with dense forest, and their summits hidden beneath snow and glaciers, and shrouded with clouds the greater part of the year. This is equally true of the Cordilleras farther south, so that the exploration of the region is attended with great difficulties. And while it is not claimed that the collections are complete, they must certainly be taken as representatives of the whole of the Andes.

The volcanoes of Colombia chiefly occur along the crest of the central range, rising above crystalline schists, and eruptive masses in the Cretaceous formation, whose upturned strata compose the ranges east and west of the central Cordillera. Heretofore, with few exceptions, the volcanic rocks examined have

[1] W. Reiss and A. Stübel: Reisen in Süd-Amerika. Geologische Studien in der Republik Colombia, I. Petrographie. 1. Die Vulkanischen Gesteine bearbeitet von Richard Küch. Berlin, 1892.

been from the Andes south of the equator. In the present instance our knowledge of them is extended to the most northern end of the great Cordilleran system.

A critical review of all previous work upon the lavas of the Andes, and its comparison with that by himself on the lavas of Colombia, and with a preliminary study of the collections by Reiss and Stübel from Ecuador, led Küch to the conclusion that essentially the same petrographical relations exist at all the volcanoes of the Andes.

With few exceptions all of these recent volcanic lavas of which we have any knowledge, are andesites and dacites, that is, rocks whose essential constituents are soda-lime-feldspar and one or more of the minerals: pyroxene, hornblende and biotite, with which is associated quartz, in the case of dacite. Recent eruptive rocks whose mineral composition falls outside of this group appear to be of rare occurrence, and are rocks closely related to andesite and dacite in composition, namely: quartz-trachyte or rhyolite on the one hand, and basalt on the other. In two instances rocks described as trachyte and quartz-trachyte by Stelzner are shown by Küch to be more properly dacite.

The known occurrences of true basalt are few, the most basic rocks being more closely related to pyroxene-andesite than to basalt, according to Küch's interpretation. Dacite, though seldom mentioned by previous investigators, is of very frequent occurrence judging from the collections by Reiss and Stübel.

The study of such abundant material naturally led Küch to first treat the lavas of Colombia as one general group of intimately connected varieties, without reference to their geographical distribution, for it became evident, as he remarks, that neither a single rock, nor a specially abundant development of any one kind, nor the association of a certain number of different rocks could be considered characteristic of any particular volcano. The same rocks with like multiplicity of development, and the same associations of rocks, repeat themselves in different localities in such a manner that what may seem to be the prevailing or the subordinate varieties in one place are more likely to appear such

because of the greater or less completeness of the material collected, than by reason of their actual scarcity or abundance in nature.

The chief feature of the report consists in the systematic description of the lavas of Colombia based upon their microscopical investigation in conjunction with their chemical analysis. The second part of the report is devoted to a description of the rocks in connection with their geographical distribution. It is to be regretted that the geological relations of the rocks with one another are not furnished at the same time.

The rocks are first discussed from a mineralogical standpoint, their mineral composition and structure being taken as the basis of classification within the general group of extrusive igneous rocks, to which they all belong. They are all embraced within the families of andesite and dacite, as defined by Rosenbusch. They present a chemical series grading from rocks relatively poor in silica and rich in lime and magnesia with sodium considerably in excess of potassium, to those comparatively rich in silica, and poor in lime and magnesia, but with sodium still in excess of potassium. The lower limits approach basalt, and the upper limits border rhyolite.

The same gradual transition exists in the mineralogical composition. At one end are pyroxene-andesites with accessory olivine, the feldspars being rather basic plagioclase. These pass into pyroxene-andesites without olivine, and into hornblende-pyroxene-andesites, and hornblende-andesites, and with increasing amounts of quartz into dacite, or quartz-andesites. In the dacites the feldspars are: plagioclase, approaching albite, and sanidine; while biotite becomes prominent among the ferromagnesian minerals.

In considering the classification of such a series of rocks, since their mode of occurrence is the same throughout, namely, that of lava streams, Küch finds the grounds of classification to be: chemical composition, mineral composition and structure. Of these, chemical composition is undoubtedly that which under like conditions of solidification controls the mineral and structural

development of the rock. Consequently he concludes that upon purely theoretical grounds a chemical classification would be the most desirable. But from the present condition of our knowledge this would be impracticable.

Moreover, he observes, that while the chemical analysis of an unaltered rock furnishes us with the proportions in which the elements existed in the molten magma, it is very probable that rocks of like chemical composition may have been derived from magmas consisting of quite different silicates (that is, possessing different molecular constitutions). And this he suggests is one of the reasons why eruptive rocks with corresponding analyses can exhibit quite different mineralogical compositions. In a foot note he observes that another cause for this phenomenon may lie in differences in the process of solidification, which may affect the rearrangement of the compounds originally in the magma. To this extent the mineralogical composition is dependent on the genesis of eruptive rocks, which he considers essentially the same as their geological mode of occurrence.

Since we are not in a position to infer the original molecular constitution of a magma from its chemical analysis, he does not consider a chemical basis of classification applicable. Nevertheless he states that a comparison of the chemical composition of the andesitic lavas with their mineralogical composition shows that certain differences of chemical composition go hand in hand with others of mineral development, and with these are also connected modifications of structure.

The mineralogical features are the most pronounced, and are therefore selected as a basis of classification. The first subdivision is based on the presence or absence of quartz, and the groups become andesites and dacites. They are not, however, distinctly separated from one another, being connected by gradual transitions. But this grouping, as a purely mineralogical one, fails, as he himself points out, in cases where quartz has not crystallized, as in certain dacitic glasses.

In the further subdivision of these groups the ferromagnesian minerals are employed as distinguishing characteristics, and the

following divisions are established under andesite: Pyroxene-andesite, hornblende-pyroxene-andesite, and hornblende-andesite. Under dacite: Pyroxene-dacite, pyroxene-hornblende-dacite, biotite-hornblende-dacite. As already remarked, the mineralogical gradation from pyroxene-andesite to biotite-hornblende-dacite is by very gradual transitions. Biotite is most abundant in the most silicious varieties.

The microscopical character and the distribution of the porphyritical minerals and of the groundmass, and the relation between the microstructure of the latter and the composition of the rocks are described in detail, and appear to be identical with those existing in the andesites and dacites of western North America. These descriptions are presented in the most satisfactory manner, but need no special notice except to call attention to the occurrence of microlites of quartz in the form of minute pyramids .003 mm. in diameter, which are an essential component of the glassy groundmasses of numerous dacites. Precisely similar microlites of quartz have been observed by the present writer in certain silicious glasses in the Yellowstone National Park, the descriptions of which have not yet been published.

The chemical composition of the rocks is shown by fifteen complete analyses and ten silica determinations. They range from 54.21 per cent. of silica to 70.22 per cent. The analyses were made from perfectly fresh and unaltered rocks, and the high percentage of water found in some cases, which reaches 3.62 per cent., is referred to the glass base. This is sometimes markedly pearlitic and hydrated. The variations in the proportions of the chemical components throughout the rock series is pointed out, and is correlated with the variations in the mineral constituents.

Attention is called to the fact that a frequent mode of alteration among these lavas leads to the development of opal, and the consequent increase in the silica percentage, so that a determination of the silica in a rock may be misleading unless the rock is known to be unaltered.

Dr. Küch's report is to be commended, not only for its scientific excellencies, but also for the form in which it has been published, and the admirable indices which render its details easily accessible.

The facts brought out by this report lead the present writer to certain conclusions regarding the nature of the volcanic ejections of the South American Andes of the greatest importance, which, however, may be modified as our information becomes more complete. In brief, it appears that the main mass of the lavas of all the volcanoes of the Andes is andesite, of variable composition in all localities. It grades into basic varieties, approaching basalt, in some places, and into acid varieties which are dacites, in others. It is probable that the basic varieties would be classed as basalts by many petrologists, but they would not constitute the more basic forms of basalt. The variability in composition and petrographical characters within these limits is pronounced, and proves the intimate relationship between all of the lavas. The almost universal absence of the most basic and most acid members of the series which occur in other regions, namely, the true basalts and rhyolites, is most significant, and, if established by future investigation, would indicate that volcanic activity in the Andes, which is still in force, had developed, by the differentiation of some magma common to the whole great Cordilleran system, a series of lavas of limited range. This series, though precisely similar to parts of others developed in other regions, especially those of Tertiary age in western North America, is wanting in the extreme forms of differentiation common to the latter—that is, in basic basalt and rhyolite. From this we may infer that the general differentiation of the magma supplying the lavas of the Andes has not reached its final stages, in which great volumes of extremely differentiated material will have been developed. It would seem to be in a much less advanced condition than the magmas supplying the lavas in Central America and Mexico, which are in turn less advanced than those of the United States, where volcanic activity is extinct or at least quiescent.

It is not to be expected that all of the volcanoes of the Andes are in exactly the same phase of differentiation, which they undoubtedly are not, but in a general way they have not progressed beyond the limits of olivine-bearing pyroxine-andesite and dacite, and may be considered as having the basalt and rhyolite phases before them. They thus show themselves as comparatively young, or perhaps middle-aged. It will be observed, however, that rhyolite occurs in small amount in Ecuador, as shown by analyses 14 and 15 in Table II.

The chemical similarity of the magmas of the Andes with those of general occurrence in western North America, which are fairly represented by the volcanic rocks of the Yellowstone National Park, is seen upon constructing a diagram of the molecular variation of the essential constituents in a manner employed by the writer[1] and also by Dakyns and Teall[2] in discussing the differentiation of molten magmas.

In Table I are given the chemical analyses of perfectly fresh rocks from Colombia, published by Dr. Küch. The general molecular character of the magmas is shown by diagram I. In the lowest part of the diagram the molecular variation of all of the essential constituents is represented, that of silica being given by the abscissas, the zero point being some distance to the left. In the middle part of the diagram alumina, soda and potash are separated from the lime, magnesia and iron-oxide, which are given by themselves in the uppermost part of the diagram, in order to avoid the confusion of lines in the lowest part. The iron is represented as ferrous oxide. The character of this diagram is quite similar to that of the diagrams for the rocks from the Yellowstone National Park in the paper on the origin of

[1] Iddings (J. P.). The mineral composition and geological occurrence of certain igneous rocks in the Yellowstone National Park. Bull. Phil. Soc., Washington, 8vo. Washington, 1890. Vol. 11, pp. 191–220.

——. The origin of igneous rocks. Bull. Phil. Soc., Washington. 8vo, Washington, 1892. Vol. 12, pp. 89–214, Pl. 2.

[2] Dakyns (J. R.) and Teall (J. J. H.). On the plutonic rocks of Garabal Hill and Meall Braec. Quart. Journ. Geol. Soc. 8vo. London, 1892, May 2, Vol. 48, part 2, No. 190, pp. 104–120.

TABLE I.

Chemical Analyses of Volcanic Lavas from Colombia.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
SiO_2	56.91	57.24	59.13	60.05	61.04	61.09	61.26	63.36	63.50	63.56	65.39	66.03	67.30	68.41	69.56
	.948	.954	.985	1.000	1.017	1.018	1.021	1.056	1.058	1.059	1.089	1.100	1.121	1.140	1.159
TiO_2				.85	.45	.95				.95					
Al_2O_3	18.18	18.02	17.00	15.59	15.72	15.96	16.15	16.35	15.34	15.43	15.49	14.57	17.55	16.08	15.65
	.178	.176	.166	.152	.154	.156	.158	.160	.150	.151	.151	.142	.172	.156	.153
Fe_2O_3	4.65	3.46	7.03	6.95	5.03	4.29	4.39	2.12	3.22	3.02	2.80	2.57	1.47	2.12	1.24
	.029	.021		.043	.031	.026	.027	.013	.020	.018	.017	.016	.009	.013	.007
FeO	3.61	4.13		.65	2.15	2.03	2.66	3.05	1.71	2.43	1.99	1.19	1.67	1.44	.91
	.050	.057		.009	.029	.028	.037	.042	.023	.033	.027	.016	.023	.020	.011
MgO	3.49	3.77		3.61	3.61	1.06	2.91	3.28	2.50	2.55	2.06	1.89	1.04	1.14	.82
	.087	.094		.090	.090	.026	.073	.082	.062	.064	.051	.047	.026	.028	.020
CaO	7.11	7.78	6.67	6.43	5.34	6.66	5.75	4.79	4.31	4.33	4.48	3.38	3.48	3.52	2.52
	.127	.138	.119	.114	.095	.115	.102	.085	.077	.077	.080	.060	.062	.063	.045
Na_2O	4.02	5.54	4.80	3.83	4.02	2.89	4.93	3.58	4.84	4.02	4.56	3.71	3.90	4.52	4.09
	.064		.077	.061	.064	.046	.079	.057	.078	.064	.073	.059	.063	.073	.066
K_2O	1.61		1.37	1.76	2.66	2.51	2.65	2.92	2.75	2.41	1.59	2.70	2.13	2.24	2.19
	.017		.014	.018	.028	.026	.028	.031	.029	.025	.016	.029	.022	.023	.023
P_2O_5	.25			.25		.22		.13		.17	.11	.09	.13		.13
SO_3										.05					
H_2O	.36	.06	.16	.47	.58	1.44	.15	.99	1.99	1.09	.55	2.07	.80	.33	2.92
	100.19	100.00		100.44	100.60	99.10	100.85	100.57	100.16	100.01	99.02	98.20	99.47	99.84	100.03

1. Pyroxene-andesite. N. W. foot of the Purgatorio. Pasto.
2. Olivine-pyroxene-andesite. Pasto.
3. Pyroxene-andesite. Cerro negro de Mayasquer.
4. Pyroxene-andesite. Azufral de Túquerres.
5. Hornblende-andesite. Peñon de Pitayó.
6. Hornblende-andesite. Loma de Ales.
7. Pyroxene-andesite. Lava of 1869. Pasto.
8. Hornblende-pyroxene-dacite, (with olivine and biotite) Cerro negro de Mayasquer.
9. Hornblende-pyroxene-dacite. Chiles.
10. Hornblende-dacite. (With biotite and pyroxene.) Llanos de las Mesas, Tajumbina.
11. Pyroxene-dacite. Cumbal.
12. Hornblende-pyroxene-dacite. Hondon, Chiles.
13. Hornblende-biotite-dacite. Azufral de Túquerres.
14. Hornblende-biotite-dacite. Azufral de Túquerres.
15. Hornblende-biotite-dacite. Loma de Ales.

TABLE II.

Chemical Analyses of Volcanic Rocks of the Andes.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	52.02	56.50	57.10	58.00	58.35	59.28	60.32	62.35	63.00	63.19	63.49	63.69	66.06	72.46	73.61
	.867	.941	.951	.966	.972	.988	1.005	1.039	1.050	1.050	1.058	1.061	1.101	1.207	1.227
TiO_2						tr				.18	-				
Al_2O_3	17.14	15.06	17.25	18.00	16.74	18.14	16.92	17.32	18.40	18.65	12.42	15.03	15.64	12.80	12.01
	.168	.147	.169	.176	.164	.177	.165	.169	.180	.183	.121	.147	.153	.125	.117
Fe_2O_3	7.94	13.52	10.75	3.72			5.88	4.51	3.96	4.01	6.41	2.51		2.32	2.27
	.049			.023			.036	.028	.024	.025	.040	.015		.014	.014
FeO	3.52			2.73	6.71	8.79	1.40			1.89	1.34	2.41	3.90		
	.048			.037	.093	.122	.019			.026	.018	.033	.054		
MnO	.85				.54	tr		.04	.10	.13	.85	.55	.71		
MgO	3.13	2.72	2.50	3.56	4.84	3.43	3.52	3.60	3.71	1.20	1.32	.80	2.57	tr	.20
	.078	.068	.062	.089	.121	.086	.088	.090	.093	.030	.033	.020	.064		.005
CaO	11.57	6.23	5.00	6.96	6.81	4.49	5.64	5.43	5.36	4.86	4.17	3.30	4.53	1.35	.89
	.206	.111	.089	.122	.121	.080	.100	.097	.095	.086	.074	.059	.080	.024	.015
Na_2O	2.38	4.55	5.12	4.36	4.69	4.26	3.83	4.29	4.22	3.69	4.90	6.54	4.00	4.48	4.34
	.038	.073	.082	.070	.075	.068	.061	.069	.068	.059	.079	.105	.064	.072	.070
K_2O	.60	1.35	2.10	2.12	1.18	1.85	2.42	3.13	2.36	1.95	1.78	2.46	2.36	4.11	3.82
	.006	.014	.022	.022	.012	.019	.025	.033	.025	.020	.019	.026	.025	.043	.040
P_2O_5	tr									.15	tr	tr			
H_2O	.28	.30	.25	.32	.31		.44	.13	.36	.07	2.88	2.23	.30	2.92	3.35
	99.45	100.23	100.07	99.77	100.17	100.24	100.37	100.80	101.47	100.07	99.56	99.52	100.09	100.44	100.53

1. Portañuela, Volcano Yate, Southern Chili.
2. Tunguragua, Ecuador.
3. Chimborazo, "
4. Chimborazo, "
5. Tunguragua, "
6. Carahuirazo, "
7. Chimborazo, "
8. Pichincha, "
9. Cachutafruto, Ecuador.
10. Tajumbina, Colombia.
11. Volcano Yate, Southern Chili.
12. Volcano Yate, "
13. Tunguragua, Ecuador.
14. Guamani, Tablon de Itulgache, Ecuador.
15. Oyacachi.

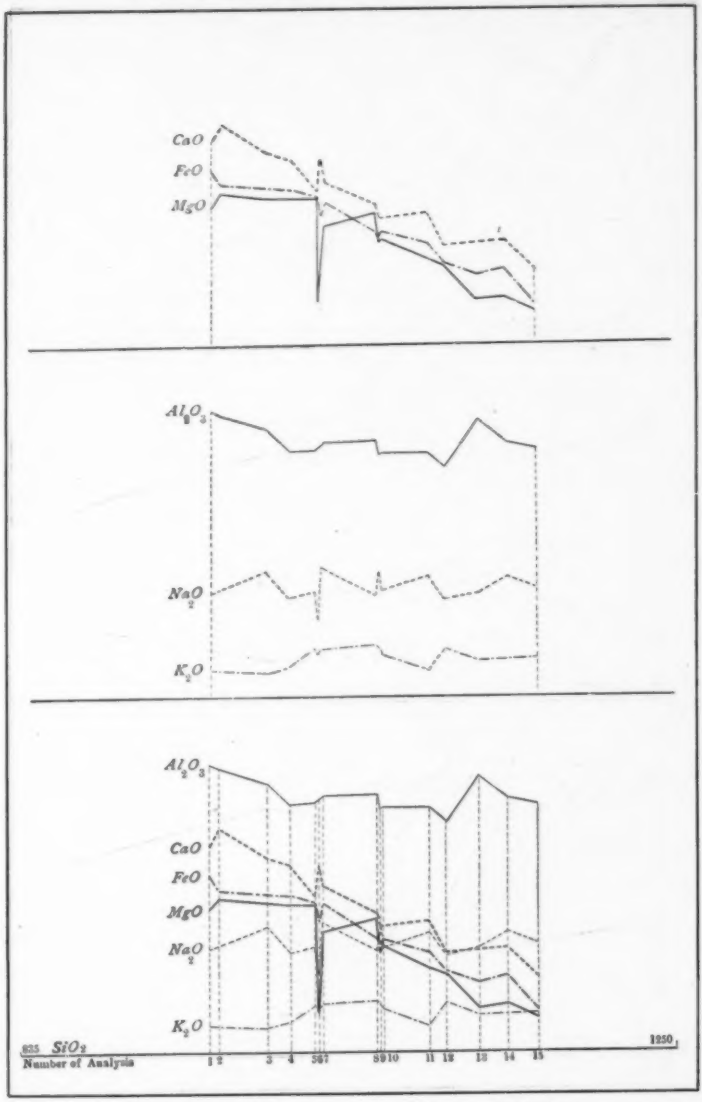


DIAGRAM 1.—Molecular variations in lavas of Colombia.

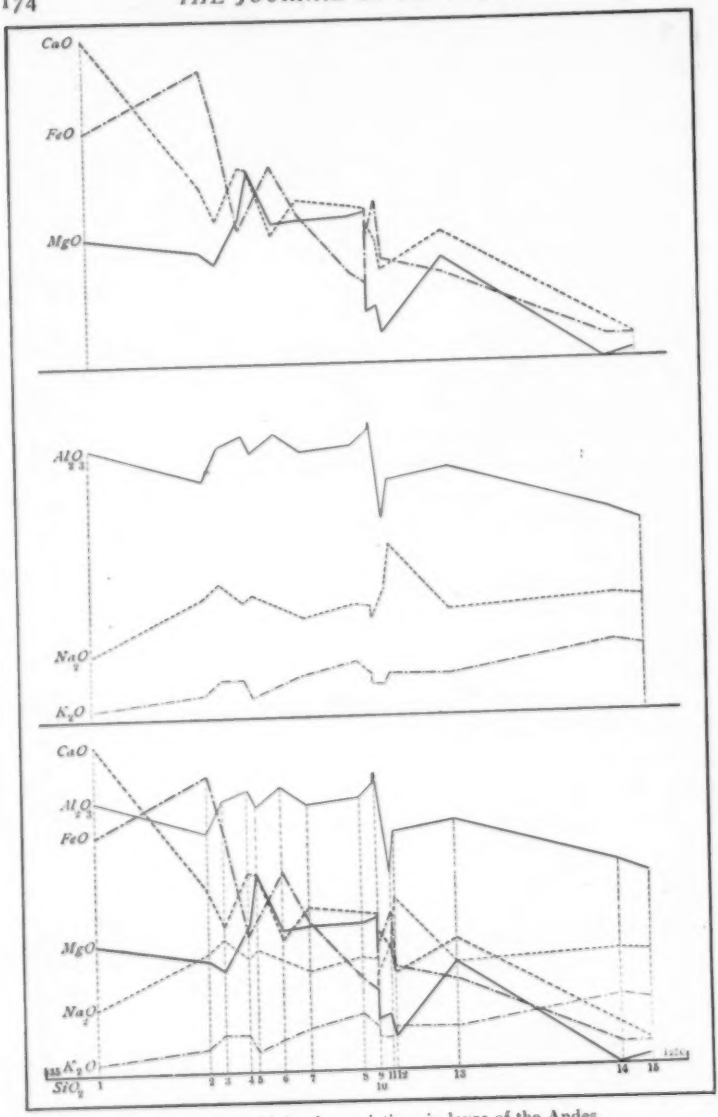


DIAGRAM 2.—Molecular variations in lavas of the Andes.

igneous rocks already cited. There is nearly the same relation between the alkalies and alumina, the soda being still more in excess of potash, and both increasing gradually toward the more silicious end of the series. The alumina maintains a high position, gradually decreasing. The lime, iron-oxide and magnesia decrease rapidly from the less silicious to the more silicious end of the series, and lie somewhat close together. In one instance there is a marked drop in the magnesia.

In Table II are given the analyses of lavas from the Andes south of Colombia, with one exception, as they have been recorded in Roth's tables of rock analyses. They present a somewhat wider range of silica percentages, from 52.02 to 73.61, but whether they have all been made from unaltered rocks is not known to the writer. An analyis of "obsidian" from Colombia is omitted, since it is extremely crude, giving 75 per cent. of silica and 3 per cent. of magnesia, with no lime. Diagram 2 expresses the molecular variations among the rocks included in this grouping. They have the same general nature as those just described, especially as to the alkalies and alumina; but the lime, iron-oxide and magnesia are more variable, which may represent the true condition of the case, or may be due to imperfect methods of analysis.

It is evident from these diagrams that the lavas of the Andes represent various phases of the differentiation of a magma which is chemically similar to that which has furnished the lavas of the Great Basin and extreme western Cordilleras in the United States, and that they belong to similar petrographical provinces.

JOSEPH P. IDDINGS.

ON THE USE OF THE TERMS POIKILITIC AND MICROPOIKILITIC IN PETROGRAPHY.

It is evident that descriptive petrography needs some generally accepted term for both a macroscopic and microscopic rock structure which is, in a certain sense, intermediate between those known as the *granular* or *microgranitic* and *graphic* or *micropegmatitic*. Areas have been observed and variously described in many types of massive rocks, whose component minerals possess neither the complete independence of optical orientation characteristic of granular structures, nor the entire optical continuity of the separated portions of two interpenetrating crystal individuals. These areas are in fact occupied by a comparatively large individual of one mineral which is more or less completely filled with crystals or grains of other minerals, arranged with no reference to one another or to their host. This structure does not usually appear as distinct from the granular except when seen as a mottling of a large cleavage surface of the enclosing mineral in a hand specimen, or as an irregular spotting of a uniformly extinguishing area under the microscope. In ordinary light, such an area may appear quite granitic, but between crossed nicols it is very distinctive.

Like the graphic or micropegmatitic structure, this relation is most commonly observed between quartz and feldspar, especially in the groundmass of quartz-porphyries; but, like that structure, it is also by no means uncommon between many other species.

Essentially this structure was figured and described at length by the writer in a quartz-porphyry from near Tryberg, in the Black Forest, in 1883,[1] although no particular name was at that time given to it. In 1886 the writer proposed the term *poikilitic*

[1] Neues Jahrbuch für Min., etc., Beilage bd. II, p. 607. Plate XII, figs. 3 and 3a, 1883.

(ποικίλος, mottled)[1] for the macroscopic equivalent of this structure which is characteristic of the hornblende of the Stony Point hornblende-picrite or cortlandtite, as it is also of the Baste and Schriesheim *schillerfels* of Germany. This had before been called "*luster mottling*," by Pumpelly[2] and Irving,[3] but this name is not capable of application to other allied structures of different appearance. In 1887 the writer described this macro-poikilitic structure in the orthoclase phenocrysts of an orthoclase-norite, belonging to the Cortlandt series.[4]

Though it is not uncommon in many minerals, it is less important and less frequent than the micropoikilitic structure in the groundmass of acid porphyritic rocks of all ages. When studying the ancient quartz-porphyries of Missouri for his thesis, Prof. E. Haworth encountered it and applied to it for the first time the name *poecilitic*.[5] In this connection the writer furnished Dr. Haworth the following from his lecture notes:

"A holocrystalline groundmass contains no amorphous or unindividualized matter whatever, and independently of differences occasioned by variations in the fineness of grain, three quite distinct types of holocrystalline structure are distinguishable. These three types are conditioned by the mutual relation of the quartz and feldspar crystals, which compose the groundmass. In the first place they may be wholly independent, thus giving rise to a granular aggregate which is well designated by the term *Microgranitic Structure*.

"In the second place a granular effect may be produced by the complete interpenetration of two individual crystals of the same size. In this case—due to the simultaneous crystallization of the two minerals from the magma—all the parts of the same individual, no matter what the size or shape, must

[1] American Journal of Science (3d ser.), vol. 31, p. 30, Jan., 1886. This term was at first incorrectly spelled *poicilitic* and subsequently corrected by Prof. Dana to its Latin form, *poecilitic* (*ib.* vol. 33, p. 139, Feb., 1887). Its preferable orthography is, however, that given above. At the time it was proposed the writer was not familiar with Breithaupt's name, *poikilit*, for bornite, nor with the designations, *terrain poecilien*, *poecilitic* and *poikilitic*, given successively by Brongniart (1829), Conybeare (1832) and Buckland (1837) to the "New Red" sandstone (cf. Bridg. Treat. II., p. 38). The totally different application of these terms could, however, produce no confusion with the one now proposed, even if they were not obsolete.

[2] Proc. Am. Acad., vol. 13, p. 260. Boston, 1878.

[3] Monogr. U. S. Geol. Survey, vol. 5, p. 42, 1883.

[4] American Journal of Science, (3d ser.) vol. 33, p. 139, 1887.

[5] Am. Geologist, vol. 1, pp. 368, 369; Pl. I, fig. 1, June, 1888.

have exactly the same optical orientation, and must hence extinguish the light between crossed nicols together. Such a structure is termed, according to the particular form it assumes, *micropegmatitic* or *granophyric*.

"In the third place a single large crystal of one of the two constituents of the groundmass may be filled with much smaller, irregularly arranged grains or crystals of the other. This would also give the general effect of a finely granular structure, although it is essentially different from either of the others above mentioned."[1]

The same structure was briefly described by Teall in a quartz-felsite from the Cheviot Hills, but without any particular designation being applied to it.[2] Harker also mentions a variety of the same structure as common in the ancient rhyolitic lavas of Wales.[3] Cross described the macro-poikilitic structure in a hornblende-peridotite, from Custer county, Colorado,[4] and the micropoikilitic structure in a rhyolite from Silver Cliff in the same district, although the connection between the two was not mentioned. In speaking of the latter rock, he says of the groundmass:

"There seems to be no isotropic matter, but individual characteristics of form and optical action are lost through the minute size of the grains which overlap and overlie each other in the thinnest attainable sections. This mixture is irregular in many cases, but in others a mottled appearance is produced in that one substance attains a uniform optical orientation in certain areas, but is filled by inclusions of the other substance. No regular intergrowth of the two can be discovered. In some spots it was clearly quartz which was the enveloping mineral."[5]

Brögger has described the groundmass of a quartz-porphyry from the region of Christiana as having a typical poikilitic structure.[6]

In his recent monograph on the Eruptive Rocks of Electric Peak and Sepulchre Mountain in the Yellowstone Park, Iddings describes the micropoikilitic structure in the groundmass of certain dike porphyrites, where he for the first time makes use of exactly this term.[7] In speaking of the Sepulchre Mountain dikes,

[1] Loc. cit. pp. 367, 368. [2] British Petrography, p. 343. London, 1888.
[3] The Bala Volcanic Series. Cambridge, 1889, pp. 22, 23.
[4] Proc. Colorado Scientific Society, vol. 2, p. 242. 1888.
[5] Ib., p. 232. [6] Zeitsch. für Kryst. u. Min., vol. 16., 1890., p. 46.
[7] Twelfth Ann. Rept. U. S. Geol. Survey, p. 589. 1892.

he calls it a "patchy structure," but says it is identical with what he before called the micropoikilitic (micropoicilitic).[1]

The micropoikilitic structure is extremely abundant in the ancient acid lavas of South Mountain,[2] in southern Pennsylvania and Maryland. It can there be proved in some cases to be of secondary origin as it occurs in plainly devitrified glasses, and it is the writer's opinion that such enclosing quartz areas will, in many cases, prove to have originated subsequent to the solidification of the rock.

I am not aware that either the macro- or micropoikilitic structures have been directly recognized by the German petrographers. I am indebted to Prof. L. V. Pirsson of New Haven for the information that the latter is recognized in France, although we have been unable to find any definition of it in print. He has shown me a section of a quartz-porphyry from Georgia, with a groundmass exactly like those from South Mountain, which Fouqué examined and pronounced an admirable example of the "*type épongeuse*," sometimes called "*structure pétrosiliceuse à ponce*." It is clearly not the same as Michel Lévy's *structure globulaire*, which he defines: "Sphérolites radiés, imprégnés de quartz orienté dans un sens optique unique. Globules imprégnés de quartz orienté, auréoles,"[3] because there the included matter is radially arranged, while in the micropoikilitic structure it is wholly irregular in its arrangement.

The references given above are sufficient to demonstrate the frequency of the rock structure here mentioned, and to show the desirability of some term to describe it. It is therefore proposed that *poikilitic* and *micropoikilitic* be employed for rock structures, whether primary or secondary, conditioned by comparatively large individuals of one mineral enveloping smaller individuals of other minerals, which have no regular arrangement in respect either to one another or to their host.

GEORGE H. WILLIAMS.

[1] Ib., p. 646.

[2] American Journal of Science, (3d ser.) vol. 44, p. 482, Dec., 1892.

[3] Roches Éruptives, p. 29. Paris, 1889.

Studies for Students.

THE MAKING OF THE GEOLOGICAL TIME-SCALE.

A CRITICAL examination of the nomenclature applied to the several divisions of the geological scale reveals a strange mixture of names, the reason for which is not evident to modern students of the science. In the list of system-names we find Carboniferous and Cretaceous, indicative of mineral characters, associated with Tertiary and Quaternary, meaning rank in some undefined order of sequence. The presence of these terms is no less mysterious than the absence of grauwacke and old-red sandstone, and primary and secondary, which were originally included. Triassic is the name of another system and records the three-fold division of the system of rocks to which it was applied; and Devonian, the name of another, reminds us of the county in England in which its rocks were first named. Observing these things, one is tempted to call in question the reliability of a systematic classification so heterogeneously compounded.

Although the older living geologists can remember back almost to the beginnings of the science, those who now are beginning their study of geology may find profit in examining the foundation principles, and the systems which have been devised, and have led to the construction and belief in the present classification — a classification, the adoption and unification of which has been thought worthy of the organization and continuance of an international Congress of Geologists. It is needless to call attention to the necessity of some systematic classification of geological formations, but as a foundation for the scientific study of the history of organisms there is need of a time-scale running back into the past, the degree of accuracy of which is known as well as the extent of its unreliability. In early attempts to classify

rocks the chronological element of the scale was not considered, but by degrees the classification has passed from a classification of rocks to a classification of periods of time.

The ancients in many respects were keen observers; they knew much about plants, animals, physical and chemical phenomena, and astronomy. But with all their learning, there appears to have been no conception formed of an ancient history of the globe and its inhabitants prior to the earlier centuries of the Christian era. One of the first geological phenomena to become generalized into a theory was that of the formation of mountains by earthquakes, as cited by Avicenus in the tenth century. The gradual change of relative level of land and sea, as seen in the encroaching of the sea or the departure of sea from the shore, gave rise to speculations regarding the great length of time required for the lifting of the whole land by this means. In the sixteenth century, Lyell reminds us, attention was drawn to the meaning of fossils, and dispute arose as to their nature. Leonardo da Vinci doubted the then current belief that the stars were the cause of the fossil shells and pebbles on the mountain sides, and advanced the idea "that the mud of rivers has covered and penetrated into the interior of fossil shells at the time when these were still at the bottom of the sea near the coast" (Lyell's Principles, p. 34).

By degrees, as Lyell has described in such fascinating manner, one after another the foundation principles arose, were discussed, controverted, and finally, by their intrinsic truth, became established. But it was not till nearly the beginning of the present century that enough was known of rocks for the formation of a general systematic classification of geological formations. The belief in a limit of six thousand years for the formation of the world was prevalent. Catastrophy was the universal resort for explanation of phenomena not then understood. And for geological purposes the Noachian deluge was an indispensable agent for the scientific explanation of even the conspicuous phenomena. For these reasons inquiry did not reach into the antiquity of the geological ages. And the first attempts at classi-

fication took little or no account of actual time-factors in geology.

Lehmann[1] (Johann Gottlob Lehmann died in St. Petersburg, 1767) is generally credited with having first proposed a classification of rocks on the basis of the order of their formation, as Primitive, Secondary, and a third class, the modern or superficial rocks made by the deluge or ordinary river action. Lehmann recognized also a direct relation of origin of the Secondary from the Primitive rocks, and thus arose the beginnings of the geological time-scale. Lehmann recognized three originally distinct kinds of rocks, or rock formations. The volcanic were separated from the others because having no particular connection with either in origin. The distinction, however, between Primitive and Secondary was fundamental. The Primitive was strictly the original, basal rock formed by crystallization from chemical solution before organisms lived; and the Secondary rocks were of secondary origin, made out of fragments of the older and always lying above them. In the original classification of Lehmann, Secondary included all the stratified rocks, as we now consider them, and in the classifications following Lehmann for some years the term Secondary was applied, though in a restricted sense.

Cuvier and Brongniart proposed the name Tertiary for the rocks classified as Secondary by Lehmann, but lying above what is now known as the Cretaceous system; and Quaternary was introduced by Morlot in 1854 for the rocks of superficial position and of glacial or fluviatile origin. Thus the nomenclature of Lehmann, which was proposed originally to indicate the derivation of the Secondary from the Primitive, was expanded on the basis of stratigraphic succession, and we observe the anomaly of a retention of two names (Tertiary and Quaternary), formed on the principle of Lehmann's terms, but his own terms, as well as his theory as a basis of classification, entirely discarded.

[1] J. G. Lehmann, Versuch einer geschichte von floetz-gebürgen, etc., Berlin, 1756. French translation cited by Lyell. Essai d'un Hist. Nat. des Couches de la Terre, 1759. See Lyell, "Principles," Vol. 1, p. 72, and Conybeare and Phillips "Geology," p. vi, and p. xlii.

Werner (1750-1817) elaborated Lehmann's scheme and modified it. He was the great teacher of geology at Freiburg, Germany, in 1815, and left his impress upon the geologists of the time, though he wrote little in the way of systematic exposition of his theories of classification. He adopted Lehmann's *Primitiv Gebirge*, but of the Secondary rocks he made a lower class, which he called transition rocks (*Uebergangsgebirge*), which were stratified, contained none or but few fossils, and were more or less oblique in position; these characteristics were observed in northern Europe, where he studied them. The remainder of the original Secondary rocks, he called *Floetzgebirge*, or flat-lying formations, and these were the equivalents of Lehmann's Secondary in the classification of the early part of the century. Later, the Wernerian school called the formations above the Cretaceous *neues Floetzgebirge*, to which, as they were studied in the Paris basin, Cuvier and Brongniart, in the latter decade of the last century, applied the name *Tertiary*, which still remains in the scheme. Werner called the looser, overlying, unconsolidated rocks *angeschwempt Gebirge*, or alluvial formations, which were afterwards, as above stated, called Quaternary by Morlot.

The classification of Lehmann, as perfected by Werner, was then as follows:

German names.	*English equivalents.*
IV. Angeschwempt gebirge,	Alluvial formations.
III. *b.* Neues Floetzgebirge,	Tertiary "
a. Floetzgebirge,	Secondary "
II. Uebergangsgebirge	Transition "
I. Urgebirge	Primitive "

These were the formations which made up the geological series as then recognized. Volcanic rocks were looked upon as local formations, and of small account in general classification. But they came to be more deeply studied by Werner, and his notion that trap was of aqueous origin led to much controversy, and gave chief prominence to his views (the Neptunian theory) and to that classification of rocks which will be next considered.

The rocks of igneous origin, although sometimes interstratified with sedimentary rocks, do not enter into the present geological time-scale, and for the present purpose further consideration of their classification is unnecessary. There has always been a remnant of rocks at the base of the scale, the consideration of which may be discarded here, because it is known chronologically only as below those rocks of which distinct evidence of their relative age is apparent. The name Primitive has been changed to Primary, and finally to Archæan, a name which was proposed by Dana, and is likely to be retained for some of the basal part of the series.

This first comprehensive classification of rocks may be called the Lehmann classification. It was based upon a structural analysis of the rocks in the order of their actual positions. The nomenclature is applied on the theory of relative order of formation.

Richard Kirwan (Geological Essays, London, 1799), claimed to be the first author to publish a general treatise on Geology in the English language. Although the book is written in a decidedly controversial spirit, the author appears to have had a thorough acquaintance with the various treatises in French, German, Latin and English, in which were expressed contemporaneous opinions regarding geological science. He was a Fellow of the Royal Societies of London and Edinburgh, member of the Royal Irish Academy, and of Academies in Stockholm, Upsala, Berlin, Manchester and Philadelphia, and Inspector General of his majesty's mines in the Kingdom of Ireland. It is probable, therefore, that he presents a fair idea of the opinions which underlay the Lehmann classification. According to Kirwan's book the rocks were originally in a soft or liquid state, the center of the earth was supposed to be hollow, or the whole earth was a solid exterior crust with immense empty caverns within. The materials of the earth were then in a state of fusion or solution, and by condensation, as time progressed, the solids were crystallized out and deposited from the chaotic fluid. The water contracted the surface and lowered upon it by sinking into the interior cavities. With the deposition of the primitive rocks

from the chaotic fluid, the water became purer. Mountains were conceived of as the local points of original crystallization which drew to them, in the process, the minerals from the general fluid. As the waters gradually withdrew by evaporation and sinking into the interior caverns, they became clarified and capable of supporting organic life.

Kirwan says (p. 26): "The level of the ancient ocean being lowered to the height of 8,500 or 9,000 feet, then and not before, it began to be peopled with fish." (Under the name fish he included shell-fish, and all other petrifactions). The plains were formed of depositions from the water of argillaceous, siliceous and ferruginous particles, mingled with those derived by erosion from the already protruding mountains. All the rocks above the height mentioned, he observed, quoting from testimony of numerous travelers, are lacking in fossils; even the limestones are crystalline or "primative" limestones and marbles. These observations were cited in refutation of Buffon's "error" in claiming that all limestones were derived from comminuted shells. According to some authorities, primitive mountains should include rocks of even less height than 8,000 feet, and the occasional presence of fossils at a greater elevation was by them accounted for by their transference to that elevation by the deluge. This account of Kirwan's will suggest the way in which the rock formation came at to be first called "*gebirge*," or mountains. Rocks were supposed to lie as they were originally formed, and thus in classifying rocks the larger aggregates were naturally mountain masses. As the conception of movements in the earth's crust with folding and displacement came into the science, the idea of classification and grouping of rocks was retained, but that their grouping was based upon present massing above the surface as mountains ceased to be accepted as truth. In the German language the term "*Gebirge*" was retained, and apparently with restricted meaning. Kirwan apparently translated the term directly into English as mountains. *Formation* however took the place of *mountain*, as applied to rock classification, in the early part of the century.

Lehmann's classification, in so far as it goes, expressed established facts of nature. There are Primitive, Secondary Tertiary and Quaternary formations, but the theory that they may be defined and determined by physical structure and present relative position is only approximately true. All crystalline rocks are not primitive, all the secondary rocks are not merely consolidated fragments of primitive rocks. Some of them are fully metamorphosed. All Tertiary rocks are not unconsolidated, as the Tertiaries of California illustrate, and we now know that altitude above the sea, or relative position of the various formations, are by no means uniform and form no criterion for their determination.

The next important advance in the classification of rocks was started by Werner and his pupils. It was a classification based upon the mineral constitution of the rocks. As the study of geology advanced Lehmann's classification was found difficult to apply with precision, and it was found to be unnatural in that rocks of apparently similar kind were dissociated, while rocks of unlike character were brought into the same class. And the mineral character and composition of rocks was found to be an accurate means of defining them. As the mineral characters became clearly understood, the rock masses received their names from the chief minerals in them, and finally the mineral nomenclature entirely superseded the nomenclature of Lehmann, and a second classification arose in which the theory of the original order of formation of the rocks gave place to the actual sequence of mineral aggregates, one after another, in examined sections of the earth's crust. In this study of minerals Werner was a conspicuous leader, and the classifications at the beginning of the present century were mainly his or adaptations of them. The form which the geological scale assumed in English geological systems is seen in typical form in Conybeare and Phillip's Geology of England and Wales, 1822.

Arranged in order from above downwards, it is as follows:

I. *Superior order.* (Neues Floetzgebirge, of Werner).

II. *Supermedial order.* (Floetzgebirge, "

(1) Chalk formation.
(2) Ferruginous sands.
(3) Oölitic system or series.
(4) { Red marle or New Red sandstone. / Newer Magnesian or conglomerate limestone.

III. *Medial, or Carboniferous order.*
(1) Coal measures.
(2) Millstone, grit and shales.
(3) Mountain limestone.
(4) Old Red sandstone.

De la Beche (Geology, 3d edition, 1833) carries out the system more completely, calling the first, or superior order, *Supercretaceous group*, and applying the terms *Cretaceous*, *Oölitic* and *Red sandstone* to three groups into which he divides the second order, and giving the third the name *Carboniferous group*. Below these he recognizes Werner's Grauwacke group, for what was the lower part of the original *Uebergängsgebirge* of his earlier classification, and below this were the *inferior stratified or non-fossiliferous rocks, and the unstratified rocks*. All of the names, it will be observed, are names indicative of mineral characters. If we turn back to the year 1817 we find the same Wernerian system applied to the classification of North American rocks by William Maclure (Observations on the Geology of the United States of America, Philadelphia, 1817). The author writes: "Necessity dictates the adoption of some system so far as respects the classification and arrangement of names. The Wernerian seems to be the most suitable, first, because it is the most perfect and extensive in its general outlines; and secondly, the nature and relative situation of the minerals in the United States, whilst they are certainly the most extensive of any field yet examined, may perhaps be found the most correct elucidation of the general accuracy of that theory, so far as respects the relative position of the different series of rocks." (Observations, etc., p. 28). The classification there set forth is as follows (in the order from below upwards):

Class I. *Primitive rocks.*

Class II. *Transition rocks*—including (1) transition limestone, (2) transition trap, (3) greywacke, (4) transition flinty slate, (5) transition gypsum.

Class III. *Floetz or secondary rocks*—including (1) old red sandstone, (2) 1st floetz limestone, (3) 1st floetz gypsum, (4) 2d variegated sandstone, (5) 2d floetz gypsum, (6) 2d floetz limestone, (7) 3d floetz sandstone, (8) rock salt formation, (9) chalk formation, (10) floetz trap formation, (11) independent coal formation, (12) newest floetz trap formation.

Class IV. *Alluvial rocks*—including (1) peat, (2) sand and gravel, (3) loam, (4) bog iron ore, (5) nagel fluh, (6) calc tuff, (7) calc sinter.

Notice in this classification that the "coal formation" is placed near the top of the secondary rocks, the "rock salt formation" near its middle, and the "old red sandstone" at its base. Later investigations did not confirm Maclure's opinion of the accuracy of Werner's system as applied to American rocks. Amos Eaton's classification of New York rocks (as exhibited in his "Geological and Agricultural Survey of the district adjoining the Erie Canal in the State of New York, Albany, 1824) is an elaboration of the same system.

In each of these classifications, except in a few cases of the retention of distinctions based upon the structural analysis, the whole nomenclature and classification is based upon mineralogical composition of the rocks. In the succeeding progress of the science a great part of the nomenclature has been replaced by other names composed on a different principle, but many of the divisions here recorded are still retained. This latter fact we may interpret to mean that distinctions based upon mineral or lithological characters are of some real and permanent value in geological classification. The history of development of this system from the first, or Lehmann's system, shows that the linear order of the series of formations in the list is based on the con-

ception of a time-scale, and a natural order of succession of the several formations.

The Wernerian classification in this respect was a correct one for the rocks in Northern Germany for which it was constructed. The English scale expressed the facts of sequence, so far as known, for the English rocks, but the attempt to fit either of them to the facts in North America emphasized their imperfection. The fundamental error in the Wernerian system was the assumption that the scale of Northern Germany was a universal scale, or, expressed in general terms, that the mineralogical constitution of a rock has any necessary relation to its place in the stratigraphical series.

The next step of progress in making the geological time-scale arose from the study of fossils. Fossils had been observed and recognized as organic remains for centuries before Lehmann and Cuvier. Lehmann, and he not the first, observed that Primitive rocks did not contain fossils, while Secondary rocks contained some, and what are now called Tertiary rocks contained them abundantly. But it was not until fossils were closely studied, their characters examined, and the species compared and classified that their importance was realized. Cuvier and Brongniart are generally credited with being the first to establish the scientific importance of fossils. (On the Mineral Geography and Organic Remains of the Neighborhood of Paris, 1808). In 1796 Cuvier had called attention to the fact that elephant bones discovered by him in the Paris basin were different from the bones of living species. In thus drawing a distinction between living and extinct animals, as implying present and past groups of living beings, the foundation was laid, not only of Palæontology, but of the whole field of investigation into the history and evolution of organisms. Cuvier and Brongniart, applying their methods of analysis to the rocks of the Paris basin, succeeded in classifying them into strata, and in defining the separate stratigraphical divisions in terms of the contained fossils. The Paris basin rocks being found to lie above the Cretaceous rocks of France and England, which represent the top member of the

secondary formation of the Lehmann classification, were named Tertiary to indicate their geological importance and their relative position in the geological scale. These naturalists did not, however, perfect the geological classification which their biological studies suggested.

William Smith in England ("Tabular view," 1790, and in unpublished maps and sections of the first and second decades of this century) emphasized the value of fossils as means of identifying strata in different regions, and others had some part in the elaboration of the principle involved, but Lyell more than any one else perfected the scheme of classification of geological formations on the basis of their fossil contents. We find him saying, in the second edition of his Elements of Geology, published in 1841, "When engaged in 1828, in preparing my work on the Principles of Geology, I conceived the idea of classing the whole series of Tertiary strata in four groups, and endeavoring to find characters for each, expressive of their different degrees of affinity to the living fauna" (p. 280). A mathematical comparison was made between the proportionate numbers of recent and of extinct species to the several divisions of the Tertiary rocks of England. The result is given in the following table (copied from his "Elements," 2d Ed., Vol. I, p. 284).

Period.	Locality.	Per Cent. of Recent Species.	Number of fossils compared.
Post-Pliocene,	Freshwater, Thames Valley,	99–100	40
Newer-Pliocene,	Marine Strata near Glasgow,	85– 90	160
Older Pliocene,	Norwich Crag,	60– 70	111
Miocene,	Suffolk, red and coralline crag,	20– 30	450
Eocene,	London and Hampshire,	1– 2	400

In the nomenclature here proposed Eocene is derived from the Greek ηως, dawn, and καίνος, recent; Miocene from μείον καίνος, less recent; Pliocene from πλειον καίνος, more recent, and the definite meaning of the nomenclature and the classification is to signify that the strata called Eocene contain the first traces of the fauna now living, the Miocene strata a small proportion of the living species, the Pliocene and Post-Pliocene more and still more of the living types, and that the whole of the Tertiary

is distinguished from the Secondary and all older beds by containing some representatives of the faunas now living.

In this earliest attempt to estimate time-relations by biological data, Lyell, as others of his time, considered species to be sharply defined natural groups, and therefore it was that the relations between a fossil fauna and its recent representatives could be expressed in mathematical terms, indicating the number of identical species. The principle underlying the classification, however, was of a deeper nature, and concerned the orderly succession of faunas and floras in time. From the application of this method of time-analysis to the Tertiary beds, it was extended to an analysis of the whole series of geological formations on the basis of their organic remains, and the Lyellian classification took the place of the older Lehmann classification as follows :

In place of	Tertiary	we have	Cainozoic.
"	"	Secondary	"	Mesozoic.
"	"	Transition	"	Palæozoic.
"	"	Primitive	"	Azoic.

This latter classification and nomenclature was gradually built up, and mainly by English Geologists, as the Lehmann and Wernerian classification was largely elaborated by German and French Geologists.

Edward Forbes proposed to divide the known faunas and floras into two great groups, Neozoic (modern) and Palæozoic (ancient). The two terms Palæozoic and Protozoic were proposed about the same time. Palæozoic by Sedgwick, for the formations known to be fossiliferous, extending from his lower Cambrian upwards to include Murchison's Silurian system, and Protozoic was a provisional name proposed for pre-Cambrian rocks which might be found to contain fossils. (Sedgwick, Proc. Geol. Soc., Vol. II, p. 675, London, 1838).

In his Silurian System, Murchison proposed Protozoic in the following words : " For this purpose I venture to suggest the term " Protozoic Rocks," thereby to imply the first or lowest

formations in which animals or vegetables appear." (Murchison, Silurian System, p. 11).

Without entering into the delicate question of apportioning the honors due to each of these great English geologists (see *American Journal of Science*, Vol. xxxix., p. 167, 1890), it may be said that in this early usage of the terms, the distinction between Protozoic and Palæozoic was ideal—and in later developments, Palæozoic has been retained for that lower great division of the scale containing distinct remains of organisms, with the Cambrian system at the bottom. To show the connection with the older nomenclature, it may be noted that Palæozoic is equivalent to Primary fossiliferous, and in this system Azoic was applied to the Primitive rocks of the Lehmann system.

John Phillips, in 1841, proposed to extend the method of classification to the whole geological series, and as his scheme was apparently the first complete classification constructed on this basis, it is offered as it appeared in "Palæozoic fossils of Devon and Cornwall," London, 1841, p. 160 (see also Penny Cyclopædia, articles Geology, Palæozoic Rocks, Saliferous system, etc).

Proposed titles depending on the series of Organic Affinities.			*Ordinary title.*
Cainozoic strata	Upper	=	Pliocene Tertiaries.
	Middle	=	Miocene Tertiaries.
	Lower	=	Eocene Tertiaries.
Mesozoic strata	Upper	=	Cretaceous system.
	Middle	=	Oölitic system.
	Lower	=	New Red formation.
Palæozoic strata	Upper?	=	Magnesian limestone formation Carboniferous system.
	Middle?		Eifel and South Devon.
	Lower	=	Transition strata. Primary srata.

(The terms are founded on the verb. ζαω or ζωω—to live, combined with καινος recent, μεσος medial or middle, and παλαιος ancient).

Professor Le Conte has proposed Psychozoic, on the same principle for the latest geological period, in which man has appeared. (See Le Conte, Elements of Geology, New York). Lyell proposed to make, on this basis, a geological time-scale and applied the term Period to each of the several divisions of the scale. Thus we find in his Geology, second edition, published in 1841, a recognition of the time element in classification, without as yet the adoption of the biological nomenclature. He gives a table "Showing the order of superposition, or chronological succession, of the principal European groups of fossiliferous rocks. Under the heading "Periods and Groups" we find the following:

I. Post-Pliocene Period	A. Recent. B. Post Pliocene.
II. Tertiary Period	C. Newer Pliocene. D. Older Pliocene. E. Miocene. F. Eocene.
III. Secondary Period	G. Cretaceous group. H. Wealden group. I. Oölite, or Jura limestone group. K. Lias group. L. Trias, or New Red sandstone group. M. Magnesian limestone group. N. Carboniferous group. O. Old Red Sandstone, or Devonian group.
IV. Primary fossiliferous Period	P. Silurian group. ? Q. Cambrian group.

(Lyell, Elements of Geology, second edition, London, 1841. Vol. ii, p. 178).

Later Lyell adopted the biological nomenclature, and was prominent among geologists in developing and elaborating the idea of the successive appearance of new types of organisms coördinate with the progress of geological time.

One of the fullest elaborations of this biological classification of the geological series to form a time-scale is found in Dana's Manual of Geology. (Manuel of Geology; treating of the principles of the science with special reference to American Geological History, by James D. Dana, 3d ed., New York, 1880.) Here we find the larger divisions called times: I, Archean; II, Palæozoic; III, Mesozoic and IV, Cenozoic times. The Palæozoic time is classified into ages, viz: The age of Invertebrates, the Cambrian and Silurian; the age of Fishes, the Devonian; the age of Coal Plants, the Carboniferous. The Mezozoic is called the age of Reptiles. The Cenozoic time includes the age of mammals and the age of man.

Each of the ages is subdivided into periods and epochs, in which the stratigraphical groups and formations form the basis, and the particular faunas and floras of each constitute the data of determination for the time divisions. Thus the Devonian age includes the following:

Periods.

Catskill
Chemung
Hamilton
Corniferous
} = Devonian Age;

and, as an example, the Corniferous Period includes the following epochs:

Corniferous
Schoharie
Cauda-galli
} = Corniferous Period.

The distinctions upon which these subdivisions are made are primarily stratigraphical, and we have still to seek a time-classification on a purely biological basis for the whole geological series.

One of the earliest attempts at systematic classification upon a purely biological basis, was made by Dr. Oppel in classifying the Jurassic formations on the basis of the successive Ammonites characterizing the beds. (A. Oppel, *Die Juraformation, Eng-*

lands, Frankreichs und des südwestlichen Deutschlands, 1856–1858). Oppel divided the lower part of the Jurassic system (the Lias) into 14 zones or beds; characterized successively from below upwards by their dominant fossil forms, chiefly ammonites.

Thus the successive zones were those of: 1, *Ammonites planorbis;* 2, *A. angulatus;* 3, *A. Bucklandi;* 4, *Pentacrinus tuberculatus;* 5, *A. obtusus;* 6, *A. oxynotus;* 7, *A. raricostatus;* 8, *A. armatus;* 9, *A. Jamesoni;* 10, *A. ibex;* 11, *A. Davœi;* 12, *A. margaritatus;* 13, *A. spinatus;* 14, *Posidonomya Bronnii.* Later classifications, elaborations or revisions of Oppel's system have been made by Wright, in 1860; Judd, 1875; Tate and Blake, 1876, etc. This method of classification recognized the principle of temporary continuance of species and of associated faunas; and it has been applied with greater or less success all through the geological scale of formations for the definition of the lesser divisions.

As early as 1838 the importance of the biological evidence in determining the time-scale was clearly enunciated by Murchison, who wrote in the introduction to the Silurian System, "that the *zoölogical* contents of rocks, when coupled with their order of superposition, are the only safe criteria of their *age.*" (The Silurian System, p. 9).

The making of the geological time-scale has now progressed to the stage when it is pretty clearly seen that the ordinary classification of geological formations, as found in our text-books, includes two distinct series of facts: (1) *geological terranes,* arranged stratigraphically and classified by their positions relative to each other and by their lithological characters; and (2) *chronological time-periods,* which may be locally marked by the stratigraphical division planes, but which depend, fundamentally, upon biological evidence for their interpretation and classification. Gilbert[1] has concisely expressed the important fact of the purely local nature of the division-planes separating the formations stratigraphically into stages, series, systems or groups in

[1] Gilbert, G. K. The work of the International Congress of Geologists. Proc. Am. Ass. Adv. Sc., August, 1887. Vol. xxxvi., p. 191.

the words: "There does not exist a world-wide system nor a world-wide group, but every system and every group is local." "The classification developed in one place is perfectly applicable only there. At a short distance away some of its beds disappear and others are introduced; farther on its stages cannot be recognized; then its series fail and finally its systems and its groups."

If we accept the correctness of this statement, it is evident that geological terranes and the stratigraphical division-planes by which they are marked, although indicative of time succession, present nothing in themselves to indicate the particular place they occupy in a time-scale. Even were the age of a particular stratum in one section accurately determined by other means, there is no stratigraphical or lithological mark upon the rock stratum, by which the corresponding age can be recognized in another section. This is not meant to imply that it is impossible to trace a stratum or formation from one section to another in the same general geological province, for in such case it is a process of tracing with slight interruption the continuity of the one terrane. But when we pass from one basin to another, the physical continuity is broken, and the stratigraphy and lithology were made on a separate basis. Hence we reach the conclusion that the perfecting of the geological time-scale must be wrought by the means, primarily, of organic remains. Chronological time-periods in geology are not only recognized by means of the fossil remains preserved in the strata, but it is to them chiefly that we must look for the determination and classification of the rocks on a time basis.

This principle is clearly enunciated in the rules adopted by the United States Geological Survey for the direction of the survey.[1] "Among the clastic rocks there shall be recognized two classes or divisions, viz: structural divisions and time divisions." "The structural divisions shall be the units of cartography and shall be designated *formations*. Their discriminations shall be based upon the local sequence of rocks, lines of separation being drawn at points in the stratigraphic column where lithologic char-

[1] Report of the Director for the Tenth Annual Report, 1890, pp. 63–65.

acters change." . . . "The time divisions shall be defined primarily by palæontology and secondarily by structure, and they shall be called *periods*" (p. 65). We have thus reached the stage in the making of the geological time-scale in which the ideas of the *geological formation* and the *geological period* have become thoroughly differentiated. The geological period as a time-unit is primarily defined by the characters of the fossil remains in the rock, so that the elaborating further and making more precise of the geological time-scale must come from a direct study of the life history of organisms as recorded in the stratigraphical formations.

H. S. WILLIAMS.

Editorials.

The publication of Professor Wright's *Man and the Glacial Period* has been the occasion of much discussion concerning some of the questions with which the book deals. The numerous and somewhat elaborate reviews have criticized adversely many points in the volume; and in spite of the fact that Professor Wright has responded to most of the reviews, and in spite of the fact that both reviews and responses have been reviewed with loud professions of disinterested impartiality, it can hardly be claimed that any specific criticism of the book has been really met. The errors which have been pointed out, some of them trivial, many of them fundamental, still remain. The unjust claims and the misrepresentations of the volume deserved the measure of criticism they have received.

It was especially the author's handling of the evidence concerning the sequence of events in the glacial period, and concerning man's antiquity in terms of geology, which occasioned the somewhat prolonged discussion. Professor Wright is certainly entitled to his opinion on both these questions, as on all others. So far as we know, this right has not been disputed. The point of criticism at the outset was that the author did not fairly represent the present state of scientific opinion on these two questions, in a book which especially professed to set forth the present status of the problems with which it dealt. The justice of the criticisms made on this basis can not be questioned. The attitude of the reviewers, or at any rate the attitude of those who called forth the discussion, was not so much that there were two or more glacial epochs, though they indicated that this was their belief, as that the author had failed to adequately present the evidence bearing on the question, and had left the discussion on this point in such shape as to mislead the public, for

whom the book was professedly written, concerning the real condition of scientific opinion. The attitude of the reviewers who first criticized the work was not that glacial man did not exist, but that the author had failed to represent the present state of scientific opinion on this question, and that existing evidence does not, in the minds of many competent observers, bear out the conclusion which Professor Wright advances, and which he advances as if it were not open to question. Instead of answering or attempting to answer the criticisms passed on the book, the responses to the reviews, and the reviews of the reviews have diverted, or attempted to divert, attention from the real criticisms, to other matters. They have shifted, or attempted to shift, the discussion from the *presentation* of the above questions in the volume under review, to the merits of the questions themselves. Shifted to this basis, the questions at issue are very different from those first raised, and may continue to be discussed long after *Man and the Glacial Period* has ceased to attract attention.

If the discussion is not at an end, it is presumably near it. Incidentally, two questions which had previously been clearly recognized and sharply emphasized by specialists have been brought into greater popular prominence than heretofore. The one question concerns the simplicity *versus* the complexity of the glacial period. The other concerns the nature of the evidence which is to be admitted into court touching the question of man's geological chronology. The first of these questions has been long before the geological world, and little that is new has been added in connection with the recent discussion. What has been said will be likely to stimulate the accumulation and critical consideration of data bearing on the question.

Concerning the question of man's antiquity in terms of geological history, the discussion has for the first time sufficiently emphasized in the popular mind the importance of the most rigid scrutiny of the evidence which claims to mark a definite stage in geological history when man's existence is beyond question. For the first time, the criteria by which such evidence

must be judged, have been widely discussed. These criteria are not new to the specialists who had earlier defined and used them. But not until now had it been so clear to so large an audience that the evidence concerning man's antiquity is primarily geological, and more than this, that it involves some of the nicest and most particular questions with which geologists have to deal. R. D. S.

***

THE article of Mr. Leverett in this number gives occasion to invite attention to certain errors that still linger in the literature of the glacial period, and that are occasionally supplemented by new ones of like nature. They grow out of the failure to distinguish between the Champlain depression and the earlier depression during which the main silts of the Mississippi Valley were deposited. A very large mass of evidence has been presented by different investigators under different auspices during the past decade that seems to us to have completely demonstrated a stage of elevation between the time of the main silt depositions associated with the outer tract of drift in the interior basin, and the time of the low-altitude formations of the St. Lawrence basin of which the deposits of the Champlain valley are the type. This stage of elevation embraced some of the most important events of the glacial period. The two stages of depression, we think, have thus been proved to be altogether distinct. In our judgment they were separated by a long interval of time, but it is not important to insist upon this in this connection. The evidences of this elevation between the two stages of depression embrace practically all the great glacial gravel trains of high gradient that are found south of the St. Lawrence basin. The nature and slope of these give clear testimony to the attitude of the land at the time of their formation. It is not asserted that there were not similar trains connected with the early stages of the earlier invasion of the ice, but the evidence on this point is as yet very scant. It certainly does not embrace the well-known high-gradient valley deposits of the interior, for these lie in valleys cut in the earlier drift and are connected with moraines that lie

north of it, except at those points at which the later drift reaches the border of the earlier. The moraines from which these high-gradient trains of gravel take their origin lie between the two areas of depression-deposits, and there is abundant and clear evidence that they were later than the one and earlier than the other. The phenomena connected with the earlier depression should, therefore, be considered quite independently of the Champlain depression. None of the agencies of the later depression can be legitimately appealed to in explaining the formations of the earlier depression. The confusion of the past, which is pardonable, should be eliminated, and further confusion avoided by the recognition of the distinctness of the two depressions.

T. C. C.

Analytical Abstracts of Current Literature.[1]

The Age of the Earth, by Clarence King. (American Journal of Science, vol. 45, Jan. 1893, pp. 1–20, with 2 Plates).

The object of Mr. King's paper is to advance the method of determining the earth's age which was employed by Lord Kelvin (Sir William Thomson), and which was based on a consideration of its probable rate of refrigeration, by applying to it new criteria. The criteria are derived from the tidal effective rigidity of the earth, and the further argument for rigidity based upon the periodic variation of latitude, and also from the researches of Dr. Carl Barus upon the latent heat of fusion of the rock diabase, and upon its specific heats when melted and solid, and upon its volume expansion between the solid and melted state. This rock was considered to represent the probable density and composition of the surface .03 or .04 of the earth's radius.

The two principal conditions within the interior of the earth upon which physical state and all purely physical reaction of the specific materials depend, being the distribution from center to surface of pressure and heat, Mr. King points out the relative values of earth-pressures deduced from Laplace's law, and two hypothetical cases of earth-temperatures. These are expressed by a diagram which shows that the temperatures maintain an almost maximum value from within .05 of radius of the surface to the center of the earth, while pressure increases steadily throughout the entire radius. Near the surface the rate of increase of heat is greater than that of pressure, and hence its effect is to overcome the results of pressure. But this relation obtains only for earth-depths of 200 miles for an earth of the Kelvin assumption. Below this the relations are completely reversed.

The results of Barus's researches furnish the means of fixing the melting points of diabase at pressures corresponding to increasing depth within the earth. These points fall in a straight line when plotted on a chart in which the coördinate axes represent temperatures and parts of the earth's radius. By plotting on the same chart curves expressing the temperature gradients of the earth for different assumptions regarding the initial excess of heat and period of cooling, it is possible to determine the extent of the couche which must remain fused in certain cases, and also the temperature gradient at the surface of the

[1]Abstracts in this number are prepared by Joseph P. Iddings, J. A. Bownocker, Henry B. Kummel, Chas. E. Peet.

earth. From a study of these curves Mr. King is led to conclude that in order to satisfy the conditions of tidal effective rigidity there can be no considerable fused couche within the upper .06 of radius. And since for a given initial temperature the temperature gradient decreases as the period of refrigeration lengthens, an excessive period produces too low a gradient at the surface to satisfy observed rates of heat-augmentation.

To meet both these requirements Mr. King selects a gradient which falls below the diabase line of fusion, and emerges at the earth's surface at a rate not less than the mean rate of 64 ft. to 1° F. This corresponds to an initial excess of 1950° C. and a period of 24×10^6 years.

Corrections which should be made to the assumed rate of refrigeration are considered, and found to modify the result but slightly.

In comparing this method of determining the age of the earth with that by Kelvin, based on tidal retardations, King contends that, from abundant geological observation plasticity must be admitted for slow deformations, enormously in excess of the small change of figure which the stress of tidal attraction would produce but for elastic resistance. And although rigidity prevents a sudden tidal deformation of five feet, it does not prevent a slow radial deformation of five miles of the surface matter. Hence it appears that no time measure can be deduced from the supposed fixing of the present ellipticity at some past date.

A very significant comparison of the earth's age is made with that of the sun, which, according to Helmholtz and Kelvin, is 15×10^6 to 20×10^6 years. It is remarked by Newcomb that the period during which the heat received by the earth from the sun has been of a temperature which would permit water to exist in a liquid state upon the earth is probably not more than 10,000,000 years. King calls attention to the fact that all we know of the earlier strata indicates a water mechanism for their deposition, and that the evidences that life was continuous in them necessitates a climate continuously suitable for the circulation of waters. All of this period therefore must have fallen within Newcomb's limits. And the earth's age, about 24,000,000 years, accords with the 15,000,000 or 20,000,000 found for the sun. J. P. I.

The Age of the Earth. By WARREN UPHAM. (American Journal of Science, March, 1893).

Mr. Upham reviews the estimates which have been made concerning the age of the earth. These range from 10,000,000 to 14,000,000,000 years. The most reliable means, the writer argues, for estimating the age of the earth is through comparing the present rate of denudation of continental areas with the greatest determined thickness of the strata referable to the successive time divisions. He assumes the rate adopted by Wallace of a continental reduction of one foot in 3000 years. Taking Houghton's estimate

for the thickness of the stratified rocks (177,200 ft.), the time required for their formation, he finds to be 28,000,000 years. Mr. Upham next assumes the thickness of the stratified rocks to be 50 miles, and the rate of land denudation to be one foot in 6000 years. This requires 84,000,000 years for their deposition. Estimates of the relative length of geological time divisions are taken from Dana, Winchell and Davis. Estimating the time since the glacial epoch to be 8000 years, the writer concludes from Davis's ratios that from 16,000,000 to 40,000,000 years have passed since life first appeared on the globe. From changes in the floras and faunas since the beginning of the tertiary, Mr. Upham thinks the length of Cenozoic time is about 3,000,000 years. Applying this to Dana's and Winchell's ratios, he concludes that about 48,000,000 years have passed since the beginning of Cambrian time. "But," says Mr. Upham, "the diversified types of animal life in the earliest Cambrian faunas surely imply a long antecedent time for their development, on the assumption that the Creator worked before then as during the subsequent ages in the evolution of all living creatures. According to these ratios, therefore, the time needed for the deposition of the earth's stratified rocks and the unfolding of its plant and animal life must be about a hundred million years." J. A. B.

Continental Problems. Annual Address by the President, G. K. Gilbert. (Bulletin of the Geological Society of America. Vol. 4, pp. 179–190).

Two-fifths of the earth's area has a mean altitude of −14,000 feet, the plateau of the deep sea; one-fourth the continental plateau a mean altitude of +1,000 feet; the remaining third includes the intermediate slopes, the areas of extreme depth and areas of extreme height. With the exception of the Antarctic continent, the continental plateau is a continuous area, whereas the plateau of the deep sea is "separated by tracts of moderate depth into three great bodies, coinciding approximately with the Pacific, Atlantic and Indian oceans." The author discusses briefly several of the unsolved continental problems. (1) By some it is suggested that the continental form is maintained by the solidity and consequent rigidity of the earth; by others the materials underlying the continental plateau are supposed to be lighter than those beneath the oceanic plateau. The difference in density is the complement of the difference in volume. In the author's view the weight of opinion and the weight of evidence is with the latter hypothesis (the doctrine of isostacy). Accepting this doctrine, the question is (2) whether the difference in density is due to difference in temperature or difference in composition. To this question no answer can be given at present. (3) For the origin of the continents the author mentions Dana's hypothesis that the continental areas cooled first and the oceanic last. Only negative results were obtained by the

author in examining the configuration of the continental mass in order to see whether it might belt the earth in a great circle. (4) The causes of differential elevation and subsidence within the area of the continental plateau is yet unknown, but in the opinion of American geologists these differential changes of level are conclusive proof that the changes are in the lithosphere and not in the hydrosphere. (5) The doctrine of the permanence of continents is regarded as not yet fully established. (6) The growth of the continents, also, is considered as a question still open to discussion. The author does not think it is fully proved that continental growth has been as steady a process as is generally believed. Most of the evidence appealed to, and the inferences drawn therefrom, concern only the minima of ancient land. The data of unconformities, by which the maxima can alone be determined, are comparatively few, are usually difficult of determination, and therefore have never been fully assembled. Further search ought to be made along these lines before this question can be considered closed.

H. B. K.

Measurement of Geological Time. By T. MELLARD READE, C.E., F.G.S. (The Geological Magazine, March, 1893).

The particles of which the sedimentary rocks are composed have been used again and again in rock building, but were all originally derived from the pre-Cambrian rocks or from igneous rocks of later date. By estimating then the average area of the pre-Cambrian and igneous rocks, the bulk of sedimentary rocks derived from them during Cambrian and post-Cambrian times, and the rate of erosion, calculation may be made of geologic time since the beginning of the Cambrian. The author assumes "for the sake of the calculation," the average area of the pre-Cambrian and igneous rocks to be one-third the whole land area of the globe. The actual bulk of the sediments accumulated since the beginning of the Cambrian is estimated as equal to the present land area two miles thick. The average rate of erosion is taken as one foot in 3000 years. From these estimates the time that has elapsed from the beginning of the Cambrian is in round numbers 95 millions of years. When the enormous length of pre-Cambrian time is added to the above, the estimate is found to agree very closely with that of Sir Archibald Geikie, *i.e.*, 100 to 600 millions years. H. B. K.

Recent Archæological Explorations in the Valley of the Delaware. By CHAS. C. ABBOTT, M.D. (Publications of the University of Pennsylvania).

This work gives the results of the author's recent investigations in the Delaware Valley, principally at two islands near the head of tide water.

Two classes of implements were found; those of argillite and those of jasper and quartz. He concludes that "an argillite-using man wandered far and wide over this country long before the use of jasper and quartz became so universal." The older "fairly well specialized argillite implements" are, in some localities, found in places at higher levels than the jasper and quartz implements, being deposited when the river flowed at higher levels than at present. However, by erosion and weathering, many of the argillite implements have been dislodged and mingled with the jasper implements along the course of the present river. The subject of palæolithic implements in the undisturbed Trenton gravels is not discussed. The burial customs, earth works, stone mounds, village sites and jasper quarries of the later inhabitants of the valley receive consideration. H. B. K.

The Drainage of the Bernese Jura. By AUGUST F. FOERSTE, with a *Supplementary Note on the Drainage of the Pennsylvania Appalachians.* By W. M. DAVIS. (From Proceedings of the Boston Society of Natural History, Vol. XXV, April 6, 1892, pp. 392–420, 2 plates).

The geological history of the Bernese Jura consists of a series of elevations and depressions, from the Triassic up to the time of the folding in late Tertiary time. The folds have a general east-northeast trend, and were formed by pressure exerted from the southeast along the whole line of the Jura folds. The folds are the strongest along the southeastern border, and decrease in altitude northwestward. They have been considerably eroded. Tertiary and Cretaceous strata are removed from the crests and upper flanks of the higher folds. The drainage lines are: (1) Longitudinal synclinal valleys; (2) Occasional shallow longitudinal valleys along the crests of the anticlines, and (3) Transverse valleys across the folds. The origin of these transverse valleys, particularly those of the Suxe and the Birse, is the question especially discussed. 1. The absence of faults at the points where the valleys cross the folds is fatal to the theory of their origin through faults, as held by Thurman. 2. Their origin from fractures, as held by Studer, Jaccard, Reutimeyer and Greppin, is improbable, for the fractures are not frequent in the Jura mountains now. That every gap due to fracture should have become a transverse connecting water channel is improbable. Some would have remained as wind gaps. 3. That they did not originate from outlets of lakes, as suggested by Phillipson, and Noe and Margerie, is manifest from the fact (1) That there were lower points by which the lakes could have been drained; (2) Some of the basins made by the folding have more than one valley cutting through the fold enclosing them. 4. The inconspicuous part played by the lateral streams on the sides of the Jura Mountains is unfavorable to the

theory of the origin of the transverse valleys through backward erosion and tapping, as suggested by Heim. Wind gaps representing the backward erosion in various stages ought to exist all over the Jura Mountains, which is contrary to fact. "This theory is particularly at fault when the strange grouping of the cross valleys along *lines* transverse to the folds is observed." 5. Their origin from superimposition is impossible, as the geological conditions required were evidently never present. 6. Mr. Foerste considers them of antecedent origin, and says: "Although the direct evidence of the progressive erosion of the streams during the rising of the folds is lacking, the systematic arrangement of several series of the transverse valleys in straight lines is strongly suggestive of the antecedent origin of the streams. This and the failure of other explanations to meet the facts are the main support of the theory."

Professor Davis notes the bearing of these conclusions on his assumption that the Appalachian streams were consequent. The consequent origin of the Jura streams was cited in support of this assumption. In view of Mr. Foerste's conclusions, Professor Davis withdraws the assumption that the "Appalachian streams were *necessarily* consequent upon the structure of the mountains when they were young," but still thinks that they *probably* were because the deformation of the Appalachians was so much stronger than that of the Jura. C. E. P.

Deep-Sea Sounding. By CAPTAIN A. S. BARKER, U.S.N. (New York: John Wiley & Sons, 133 pp. 3 maps).

This volume gives a brief account of the work done by U. S. S. Enterprise in deep-sea sounding on a cruise from Norfolk, Va., to China and return. The route taken was *via* Cape de Verde Islands, Cape of Good Hope, along the coast of South Africa, thence to Madagascar, the Comoro Islands and Zanzibar, thence across the Indian Ocean to the straits of Sunda, thence to China. Soundings were taken every 100 miles, and sometimes oftener. On the return voyage a line of soundings was made from Wellington, New Zealand to Magellan Straits, and from Montevideo northward off the east coast of South America, at varying distances, as far north as the Bermudas.

On charts accompanying the volume are recorded the depth of the soundings and data concerning the nature of the material of the sea bottom. The deepest sounding was 4,529 fathoms, made to the north of Porto Rico, the position being within forty miles of the deepest sounding (4,561 fathoms) ever taken in the Atlantic Ocean. Two submarine peaks were discovered in the South Atlantic Ocean about 20° west of Cape Town, at a depth of 731 and 979 fathoms. The materials brought up were corals, sand and shells. About 20° east north-east of Montevideo an extensive sand bank was found at a depth of 390 to 500 fathoms. The text is made up of extracts from the ship's log and the captain's private journal. C. E. P.

Observations and Experiments on the Fluctuations in the Level and Rate of Movement of Ground-water on the Wisconsin Agricultural Experiment Station Farm, and at Whitewater, Wisconsin. By FRANKLIN H. KING, Professor of Agricultural Physics, University of Wisconsin. (Washington, D. C.: U. S. Department of Agriculture, Weather Bureau, Bulletin No. 5. 75 pp. Ill., 6 plates).

This bulletin records observations made on the fluctuations of the underground water level from 1888 to July 1892. For the purpose of these observations forty-six wells, varying in depth from five feet to eighty-four feet, within an area 1,200×1,000 feet were available. There are certain short-period changes in level of the ground-water. (1) Those due to seasonal and annual changes in rainfall. (2) Seasonal and mean annual changes in soil temperature develop fluctuations by modifying the rate of percolation and of underground drainage, the changes in temperature influence the viscosity of liquids, and variations in viscosity affect the flow of water through capillary tubes of the soil. Besides these changes the surface of the ground-water level is subject to many slight oscillations, some of them almost beyond measurement. "Oscillations of atmospheric pressure of almost every character affect the under groundwater surface. The longer period barometic changes associated with cyclones, the shorter period changes which accompany thunder storms, and semi-diurnal barometric changes have their corresponding fluctuations in the ground-water." It was found that in recording the rate of flow of a tile drain, a spring and an artesian well, that all three had fluctuations synchronous with the barometric fluctuations. The magnitude of these influences is so great that Prof. King thinks the change in flow from large subterranean drainage areas can be registered upon many rivers and lakes. "The equilibrium of the water, in the capillary soil spaces above the surface of the ground-water, is so unstable that apparently the slightest cause is sufficient to upset it, causing the water to flow out of the non-capillary spaces, but only to be returned again on a moment's notice." The diurnal changes in soil temperature produce corresponding rises and falls of the water surface; "the passage of a train, even where the water is twenty feet below the surface, causes the non-capillary spaces to fill up and empty again as the weight approaches and recedes." No fluctuations due to lunar or solar tidal disturbances were observed. C. E. P.

ACKNOWLEDGMENTS.

The following papers have been donated to the library of the Geological Department of the University of Chicago.

FROM THE PUBLISHERS.

—The Interpretation of Nature, by Nathaniel Southgate Shaler, Professor of Geology in Harvard University. Published by Houghton, Mifflin & Co., Boston and New York. 16mo. 305 pp.

—Deep-Sea Sounding, A Brief Account of the Work Done by the U. S. S. Enterprise in Deep-Sea Sounding during 1883–1886, by Captain A. S. Barker, U. S. N. Published by John Wiley & Sons, New York. 133 pp. 3 maps.

MAINLY FROM THE AUTHORS.

HICKS, HENRY, M.D., F.R.S., Sec. G. S.

—On Some Undescribed Fossils from the Menevian Group (with a note on the Entomostraca by Professor T. Rupert Jones). 13 pp., 3 pl.—Quart. Journal Geol. Soc., May, 1872.

—On the Succession of the Ancient Rocks in the Vicinity of St. David's, Pembrokeshire, with Special Reference to those of the Orenig and Llandeilo Groups, and their Fossil contents. 27 pp., 3 pl.—Ibid., May, 1875.

—On the Metamorphic and Overlying Rocks in the Neighborhood of Loch Maree, Ross-shire. 8 pp., Ill.—Ibid., Nov., 1878.

—Additional Notes on the Dimetian and Pebidian Rocks of Pembrokeshire (with an appendix by T. Davies, Esq., F.G.S.). 16 pp., 1 pl.—Ibid., May, 1878.

—On a new Group of Pre-Cambrian Pocks (the Arvonian) in Pembrokeshire (with an appendix by T. Davies, Esq., F.G.S.). 16 pp., Ill.—Ibid., May, 1879.

—Pre-Cambrian Volcanos and Glaciers. 3 pp.—Geol. Mag., Nov., 1880.

—On Plant-Remains from Denbighshire Grits, Corwen, N. Wales. 16 pp., Ill., 1 pl.—Quart. Jour. Geol. Soc., Aug., 1881.

—Notes on Prototoxites and Pochytheca discovered by Dr. Hicks in the Denbighshire Grits of Corwen, N. Wales. By Principal Dawson, LL.D., F.R.S., etc.—Ibid., May, 1882.

—Additional Notes on the Land Plants from the Pen-y-glog Slate-quarry near Corwen, N. Wales. 6 pp., 1 pl.—Ibid., Feb., 1882.

—On the Metamorphic and Overlying Rocks in Parts of Ross and Invernessshires (with notes on the Microscopic Structure of some of the Rocks by Professor T. G. Bonney, M.A., F.R.S., Sec. G. S.) 28 pp., Ill., 1 pl.—Ibid., May, 1883.

—The Succession in the Archæan Rocks of America, compared with that in the Pre-Cambrian Rooks of Europe. 23 pp.—Proc. Geologists' Assoc., Vol. VIII, No. 5.

—On Some Recent Views Concerning the Geology of the Northwest Highlands of Scotland. 23 pp.—Ibid., Vol. IX, No. 2. (1885).

—On the Cambrian Conglomerates resting upon and in the vicinity of some Pre-Cambrian Rocks (the so-called Intrusive Masses) in Anglesey and Caernarvonshire. 14 pp.—Quart. Jour. Geol. Soc., Feb., 1884.

—On some Rock Specimens collected by Dr. Hicks in Anglesey and N. W. Caernarvonshire. By T. G. Bonney. 8 pp.—Ibid., Feb., 1884.

—Further Proofs of the Pre-Cambrian Age of Certain Granitoid, Felsitic and other Rocks in N. W. Pembrokeshire. 13 pp. Ibid, Aug., 1886.

—Results of recent Researches in some Bone-Caves in North Wales (Flynnon Beuno and Cae Gwyn); with a note on the Animal Remains, by W. Davies, Esq., F.G.S. 19 pp., Ill.—Ibid., Feb., 1886.

—The Flynnon Beuno and Cae Gwyn Caves. 6 pp., Ill.—Geol. Mag., Dec., 1886.

—The Cambrian Rocks of North America. 4 pp.—Geol. Mag., April, 1887.

—On Cae Gwyn Cave, North Wales (with a note by C. E. De Rance, Esq., F.G.S. 17 pp., Ill.—Quart. Jour. Geol. Soc., Aug., 1888.

—Prehistoric Man in Britain. 8 pp.—Trans. Hertfordshire Nat. Hist. Soc. Vol. V, Part 5, June, 1889.

—On Some Recently Exposed Sections in the Glacial Deposits at Hendon. 10 pp., Ill., pl.—Quart. Jour. Geol. Soc., Nov., 1891, Vol. XLVII.

—On the Discovery of Mammoth and other Remains in Endsleigh Street and on Sections Exposed in Endsleigh Gardens, Gordon Street, Gordon Square and Tavistock Square, London. 16 pp., Ill.—Ibid., Aug., 1892

—Fauna of the Olenellus Zone in Wales. 4 pp., Ill.—Geol. Mag., Jan., 1892.

—Pre-Cambrian Rocks Occurring as Fragments in the Cambrian Conglomerates in Britain. 3 pp.—Geol. Mag., Nov., 1890.

—The Effects produced by Earth Movements on Pre-Cambrian and Lower Palæozoic Rocks in Some Sections in Wales and Shropshire. 3 pp.—Geol. Mag., Dec., 1890.

HOFFMAN, G. CHRISTIAN.

—Canadian Apatite. 14 pp.—Geol. Sur. of Canada, 1879.

—Report on Canadian Graphite, with special reference to its employment as a Refractory Material. 24 pp., Geol. Sur. of Canada, 1876–77.

—Chemical Contributions to the Geology of Canada, from the Laboratory of the Survey. 25 pp.—Geol. Sur. of Canada, 1880.

—Chemical Contributions to the Geology of Canada, from the Laboratory of the Survey. 21 pp.—Geol. Sur. of Canada, 1881.

—Chemical Contributions to the Geology of Canada, from the Laboratory of the Survey. 16 pp.—Geol. Sur. of Canada, 1883.

—Chemical Contributions to the Geology of Canada Coals and Lignites of the Northwest Territory. 44 pp., with tables.—Geol. Sur. of Canada, 1884.

—Chemical Contributions to the Geology of Canada, from the Laboratory of the Survey. 29 pp.—Geol. Sur. of Canada, 1885.

—Chemical Contributions to the Geology of Canada, from the Laboratory of the Survey. 44 pp.—Geol. Sur. of Canada, 1887, Part T, Annual Report, 1886.

—Chemical Contributions to the Geology of Canada, from the Laboratory of the Survey. 58 pp.—Geol. Sur. of Canada, 1888, Part T, An. Rep., 1887.

—Chemical Contributions to the Geology of Canada, from the Laboratory of the Survey. 68 pp., with table.—Geol. Sur. of Canada, 1890, Part R, An. Rep., Vol. IV, 1888–89.

—Annotated List of the Minerals occurring in Canada. 41 pp. (65–105).—Trans. Roy. Soc. of Canada, Vol. VII, Section III, 1889–90.

—On a Peculiar Form of Metallic Iron found on St. Joseph Island, Lake Huron, Ontario. 4 pp. (39–42), with plate.—Trans. Roy. Soc. Canada, Vol. VIII, Section III, 1890.

—On the Hygroscopicity of Certain Canadian Fossil Fuels. 5 pp., with tables. (Pp. 41–45).—Trans. Roy. Soc. Canada, Vol. VII, Section III, 1889–90.

HOFFMAN, HORACE ADDISON (and DAVID STARR JORDAN).

—A Catalogue of the Fishes of Greece, with notes on the names now in use and those employed by classical authors. 56 pp. (230–285).—Proc. Acad. Nat. Sci., Philadelphia, Aug. 17, 1892.

HOLLICK, ARTHUR.

—The Palaeontology of the Cretaceous Formation on Staten Island. 2 pp (Pp. 259–260).—Am. Jour. Sci., Vol. XLIV, Sept., 1892.

HOLMES, WM. H.

—Glacial Phenomena in the Yellowstone Park. 6 pp. (203–208), Ill.—Am. Nat., March, 1881.

—Fossil Forests of the Volcanic Tertiary Formations of the Yellowstone National Park. 8 pp. (125–132), Ill.—Bull. U. S. Geol. and Geog. Survey, Vol. V, No. 1, Feb. 28, 1879.

HOUSTON, PROFESSOR EDWIN J.

—A Huge Boulder. 2 pp., Ill.—Journal Franklin Institute.

HUBBARD, LUCIUS L.

—Beiträge zur Kenntniss der Nosean-führenden Auswürflinge des Laacher Sees. 50 pp., 3 pl., Nov., 1886.

HUXLEY, THOMAS H., LL.D., F.R.S.

—The Crocodilian Remains found in the Elgin Sandstones, with remarks on the Ichnites of Cummingstone. 58 pp., with geol. map and 12 accompanying plates.—Memoirs of the Geological Survey of the United Kingdom, 1877.

HYATT, ALPHEUS.

—Jura and Trias at Taylorville, California. 17 pp. (396–412).—Bull. Geol. Soc. Am., Vol. III, July, 1892.

—The Jurassic and Cretaceous Ammonites, collected in South America by Professor James Orton, with appendix upon the Cretaceous Ammonites of Professor Hartt's collection. 8 pp. (364–372).—Proc. Bos. Soc. Nat. Hist., Vol. XVII, Jan. 20, 1875.

—Remarks on the Porphyries of Marblehead. 5 pp. (220–224).—Proc. Bos. Soc. Nat. Hist., Vol. XVIII, Jan. 19, 1876.

—Sponges considered as a distinct Sub-Kingdom of Animals. 6 pp. (12–17).—Proc. Bos. Soc. Nat. Hist., Vol. XIX, Nov. 1, 1876.

—Carboniferous Aphalopods., Ill. 28 pp. (329–356). Geol. Sur. of Texas.—Second An. Rep., 1890.

—Genetic Relations of Stepanoceras. 41 pp.—Proc. Bos. Soc. Nat. Hist., Vol. XVIII, June 7, 1876.

—Biological Relations of the Jurassic Ammonites.—Proc. Bos. Soc. Nat. Hist., Vol. XVII. 2 pp. (240–241), Dec. 16, 1874.

—On Reversions among the Ammonites. 22 pp., Oct. 5, 1870.

—Values in Classification of the Stages of Growth and Decline, with Propositions for a New Nomenclature.—American Naturalist, Oct., 1888. 17 pp. (Pp. 872–888).

—Genetic Relations of the Augulatidæ.—Proc. Bos. Soc. Nat. Hist., Vol. XVII. 19 pp. (Pp. 15–33). May 20, 1874.

—Abstract of Larval Theory of Origin of Tissue.—Am. Jour. Sci., Vol. XXXI, May, 1886. 16 pp. (Pp. 332–347).

—Geology and Palæontology. The Protoconch of Cephalopoda. 1 p., 1884.

—The Larval Theory of the Origin of Cellular Tissue. 5 pp., May, 1884.

—Observations on Polyzoa Sub-Order Phylactolæmata, with nine plates and numerous cuts.—From Proc. Essex Institute, Vols. IV and V. 103 pp., 1866–68.

—Larval Theory of the Origin of Cellular Tissues.—Proc. Bos. Soc. Nat. Hist., Vol. XXIII, March 5, 1884, Synopsis I–IV. 119 pp. (45–163).

—Genesis of the Aristidæ, 14 plates. 238 pp.+xi. Ill.—Memoirs of the Museum of Comparative Zoölogy, Harvard College, Vol. XVI, No. 3, Nov., 1889.

IDDINGS, JOSEPH PAXSON (and CARL BARUS).

—Note on the Change of Electric Conductivity Observed in Rock Magmas of Different Composition on Passing from Liquid to Solid. 8 pp. (242–249). Ill.—Am. Jour. Sci., Vol. XLIV, Sept., 1892.

—The Eruptive Rocks of Electric Peak and Sepulchre Mountain, Yellowstone National Park. 86 pp. (577–664), 8 pl., geol. map,—Twelfth An. Rep. U. S. G. S., 1890–91.

JENSSEN, ERNST.

—Beiträge zur Krystallographischen Kenntniss organischer Verbindungen. 32 pp., Ill., 1889.

JOHNSON, LAWRENCE C.

—The Grand Gulf Formation.—Science, Sept. 9, 1892.

—Grand Gulf Formation.—Science, Oct. 28, 1892.

—The Grand Gulf Formation of the Gulf States. 4 pp., Ill. (213–216).—Am. Jour. Sci., Vol. XXXVIII, Sept., 1889.

—The Chattahoochee Embayment. 5 pp. (128–132).—Bull. Geol. Soc. Am., Vol. III, 1891.

—The Nita Crevasse. 5 pp. (120–125). Ill.—Bull. Geol. Soc. Am., Vol. II.

HALLOCK, W.

—Report of Committee on Rate of Increase Downward of Underground Temperature. 3 pp., with table.—Brit. Assoc. Ad. Sc., 1892.

KERR, W. C. (and GEO. B. HANNA).

—Ores of North Carolina. 235 pp. (125–359), 27 pl., geol. map and numerous cuts.—Geol. of North Carolina, Vol. II, Chap. II, 1888.

KEYES, CHARLES R.

—Lower Carbonic Gasteropoda from Burlington, Iowa. The American Species of Polyphemopsis. Sphaerodoma: A Genus of Fossil Gasteropods. 126 pp. 283–309).—Proc. Acad. Nat. Sci. of Philadelphia, Sept. 24, 1889.

—The Principal Mississippian Section. 18 pp. (283–300), 9 pl., Vol. III.—Bull. Geol. Soc., Am., June, 1892.

—On the Fauna of the Lower Coal Measures of Central Iowa, and Descriptions of Two New Fossils from the Devonian of Iowa. 27 pp., 1 pl.—Proc. Acad. Nat. Sci., Philadelphia, July 31, 1888.

—The Redrock Sandstone of Marion County, Iowa. 4 pp. (273–276), Ill.—Am. Jour. Sci., Vol. XLI, April, 1891.

—Surface Geology of Burlington, Iowa. 6 pp. (1049–1054).—Am. Naturalist, Vol. XXII, Dec., 1888.

—The Coal Measures of Central Iowa, and Particularly in the Vicinity of Des Moines. 9 pp. (396–404), Ill.—Am. Geol., Dec. 1888.

—Genesis of the Actnocrinidæ. 12 pp. (243–254), 3 pl.—Am. Naturalist, March, 1890.

—The Sedimentary Habits of Platyceras. 4 pp. (269–272).—Am. Jour. Sci., Vol. XXXVI, Oct. 1888.

—Discovery of Fossils in the Limestones of Frederick County, Maryland. 3 pp., Ill.—Johns Hopkins University Circulars, No. 83.

—On Some Fossils from the Lower Coal Measures at Des Moines, Iowa. 6 pp. (23–28).—Am. Geol., July, 1888.

—On the Attachment of Platyceras to Palæocrinoids, and its Effects in Modifying the Form of the Shell. 13 pp., 1 pl.—Proc. Amer. Philos. Soc., Vol. XXV, No. 128, Oct. 1888.

—Synopsis of American Carbonic Calyptræidæ. 32 pp. (150–181), 1 pl., 1 table.—Proc. Acad. Nat. Sci., Philadelphia, 1890.

—Review of the Progress of American Invertebrate Palæontology for the year 1890. 7 pp. (327–333).—Am. Nat., April, 1891.

—The Naticoid Genus Strophostylus. 7 pp., 1 pl.—Am. Nat., Dec. 1890.

—Review of the Progress of American Invertebrate Palæontology for the year 1889. 8 pp. (131–138).—Am. Nat., Feb. 1890.

—The Petrography and Structure of the Piedmont Plateau in Maryland, by George Huntington Williams, of Johns Hopkins University, with a Supplement on a Geological Section Across the Piedmont Plateau in Maryland. 22 pp. (301–322), 1 pl., Ill.—Bull. Geol. Soc. Am., Vol. II, March, 1891.

—Stratigraphy of the Carboniferous in Central Iowa. 16 pp. (277–292), 2 pl.—Bull. Geol. Soc., Am., Vol II, March, 1891.

—An Annotated Catalogue of the Mollusca of Iowa. 23 pp.—Bull. Essex Inst., Vol. XX, 1889.

—Fossil Faunas in Central Iowa. 24 pp. (242–265).—Proc. Acad. Nat. Sci., Philadelphia, April 28, 1891.

—Remarks on the Perisomic Plates of the Crinoids. 2 pp.

—Soleniscus: Its Generic Characters and Relations. 5 pp. (420–424), 1 pl.—Am. Nat., May, 1889.

—Proposed Economical Geological Survey of Iowa. 6 pp.—Iowa State Register, July 12, 1891.

KNOP, DR. A.
—Beitrag zur Kenntniss der in den Diamantfeldern von Jagerfontein (Südafrika) vorkommenden Mineralien und Gesteine. 16 pp., Ill.—Aus dem Bericht über die XXII Versammlung des Oberrheinischen geologischen Vereins.

KNOWLTON, F. H., B.S.
—Additions to the Flora of Washington and Vicinity, from April 1, 1884, to April 1, 1886. 27 pp. (106–132).—Proc. Biol. Soc., Wash., Vol. III, 1884–86.
—Description of a Problematic Organism from the Devonian of the Falls of the Ohio. 8 pp., Ill. (202–209).—Am. Jour. Sci., Vol. XXXVII, March, 1889.
—Description of Fossil Woods and Lignites from Arkansas. 19 pp. (249–267), 3 pl., Chap. XXVI, An. Rep. Geol. Surv. Ark., 1889, Vol. II.
—A Monograph on Stigmaria. 2 pp.—Bot. Gazette, Vol. XIII, No. 2, Feb. 1888.
—The Fossil Flora of the Bozeman Coal Field. 2 pp. (153–154).—Proc. Biol. Soc., Wash., Vol. VII, July, 1892.
—List of Plants collected by Mr. Charles L. McKay at Nushagak, Alaska, in 1881, for the U. S. Nat. Museum. 12 pp. (213–224).—Proc. U. S. Nat. Mus., 1885.
—The Fossil Wood and Lignites of the Potomac Formation. 8 pp. (99–106).—Am. Geol., Vol. III, No. 2, Feb. 1889.
—The Fossil Wood and Lignites of the Potomac Formation. 2 pp. (207–208), March, 1889.—Proc. A. A. A. S., Vol. XXXVII.
(AND LESQUEREUX, LEO.)
—Description of Two Species of Palmoxylon—one new—from Louisiana. 3 pp. (89–91), 1 pl.—Proc. U. S. Nat. Mus., 1888.
—New Species of Fossil Wood (Araucarioxylon Arizonicum) from Arizona and New Mexico. 4 pp. (1–4), 1 pl.—Proc. U. S. Nat. Mus., 1888.
—Description of Two New Species of Fossil Coniferous Wood from Iowa and Montana. 4 pp. (5–8), 2 pl.—Proc. U. S. Nat. Mus., 1888.
—Directions for Collecting Recent Fossil Plants. 46 pp., Ill.—Part B, Bull. U. S. Nat. Nat. Mus., No. 39, 1891.
—A Revision of the Genus Araucarioxylon of Kraus, with Compiled Descriptions and Partial Synonomy of the Species. 17 pp. (601–617).—Proc. U. S. Nat. Mus., Vol. XII, No. 784.
—Fossil Wood and Lignite of the Potomac Formation.—Bull. U. S. G. S., No. 56. 72 pp., 7 pl., 1889.
—List of Fossil Plants collected by I. C. Russell, at Black Creek, near Gadsden, Ala., with descriptions of several new species. 5 pp. (83–87), 1 pl.—Proc. U. S. Nat. Mus., 1888.

KUNISCH, HERMANN VON.
—Ueber eine Saurierplatte aus dem oberschlesischen Muschelkalke. 23 pp. (671–693), 2 pl.—Zeitschr. d. Deutsch. geolog. Ges. Jahrg., 1888.
—Labyrinthodonten-Reste des oberschlesischen Muschelkalkes. 10 pp. (377–386), 1 pl.—Zeitschr. d. Deutsch. geolog. Ges., 1890.
—Voltzia Krappitzeusis nov. spec. aus dem Muschelkalke Oberschlesiens. 5 pp., Ill. (894–898).—Zeitschr. d. Deutsch. geolog. Ges., 1886.
—Die Meteoriten unter besonderer Berücksichtigung der schlesischen. 8 pp., January, 1883.
—Dactylolepis Gogolinensis nov. spec. 8 pp. (587–594), 1 pl.—Zeitschr. d. Deutsch. geolog. Ges., 1885.

KUNZ, GEORGE F.
—The Gems of the National Museum. 8 pp. (823–830).—Pop. Soc. Month., April, 1886.
—Our Five New American Meteorites. 12 pp. (312–323), Ill.—Am. Jour. Sci., Vol. XL, Oct. 1890.
—Mineralogical Notes on Fluorite, Opal, Amber and Diamond. 3 pp. (72–74).—Am. Jour. Sci., Vol. XXXVIII, July, 1889.
—(1) Tysonite and Bastnasite; (2) Meteoric Iron from Indian Valley Township, Virginia; (3) Anatase; (4) Sapphire. 3 pp.—Mineral. Mag., Vol. IX, No. 44.

—Precious Stones. 4 pp. (445–448).—Abstract from Min. Res., U. S. for 1889–90. U. S. G. S.

—Precious Stones. 34 pp.—Franklin Inst., Sept. and Oct. 1890.

—Precious Stones. 25 pp. (555–579), with tables.—Abstract from Min. Res. U. S., for 1887. U. S. G. S.

—American Gems and Precious Stones. 18 pp. (482–499).—Abstract from Min. Res. U. S., 1883. U. S. G. S.

—On the New Artificial Rubies. 10 pp., Ill.—Trans. New York Acad. Sci., Oct. 4, 1886.

—On the Tourmaline and Associated Minerals of Auburn, Maine; Andalusite from Gorham, Maine; the White Garnet from Wakefield, Canada. 4 pp.—Am. Jour. Sci., Vol. XXVII, April, 1884.

—Mineralogical Notes. 22 pp. (237–258), Ill.—Proc. A. A. A. S., Vol. XXXIV, Ann Arbor Meeting, Aug. 1885.

—The Meteorites from Glorieta Mountain, Santa Fé Co., N. Mex.—6 pp. (329–334), 6 pl. and 1 cut.—Annals N. Y. Acad. Sci., Vol. III, No. 11, 1885.

—Walden Ridge, Tenn., Meteorite. 1 p.—Am. Jour. Sci., Vol. XXXIV, Dec. 1887.

—On Two New Masses of Meteoric Iron. Meteoric Iron from Linnville Mountain, Burke Co., N. Car. Meteoric Iron from Laramie Co., Wyoming. 3 pp. (275–277), 1 pl.—Am. Jour. Sci., Vol. XXXVI, Oct. 1888.

—Meteoric Iron from Jenny's Creek, Wayne Co., W. Va. 4 pp. (145–148), Ill.—Am. Jour. Sci., Vol. XXXI, Feb. 1886.

—Precious Stones, Gems and Decorative Stones in Canada and British America. 16 pp.—Rep. Dept. Min. Statistics, Geol. Surv., Can., 1888.

—On Three Masses of Meteoric Iron from Glorieta Mountain, near Canoncito, Santa Fé Co., N. Mex. 4 pp., 4 pl. and 1 cut.—Am. Jour. Sci., Vol. XXX, Sept. 1888.

(AND WEINSCHENK, ERNEST).

—On Two Meteoric Irons. 3 pp. (424–426), 1 pl.—Am. Jour. Sci., Vol. XLIII, May, 1892.

—Hollow Quartz from Arizona. 1 p., 1 pl.—Am. Jour. Sci. Vol. XXXIV, Dec. 1887.

—Precious Stones. 11 pp. (595–605), with tables.—Abst. Min. Res. U. S., 1888. U. S. G. S.

—Precious Stones. 8 pp. (437–444), tables.—Abst. Min. Res. U. S., 1885. U. S. G. S.

—Precious Stones. 60 pp. (723–782), tables.—Abst. Min. Res. U. S., 1883–84. U. S. G. S.

—Mineralogical Notes. 3 pp. (222–224), Ill.—Am. Jour. Sci., Vol. XXXVI, Sept. 1888.

—Two New Meteorites from Carroll County, Ky., and Catorze, Mexico. 8 pp., Ill.—Am. Jour. Sci., Vol. XXXIII, March, 1887.

—Chattanooga County, Ga., Meteorite. 2 pp. (471–472), 1 map, Ill.—Am. Jour. Sci., Vol. XXXIV, Dec. 1887.

—Madstones and their Magic. 2 pp. (286–287).—Science, Vol. XVIII, No. 459, Nov. 20, 1891.

—Diamonds and Diamond-Fields. 3 pp., Ill.—Appleton's Phys. Geog., 1887.

—A New Method of Engraving Cameos and Intaglios. 2 pp., Ill.—N. Y. Acad. Sci., May 25, 1884.

(AND WEINSCHENK, E., PH.D.)

—Farmington, Washington Co., Kansas, Aerolite. 3 pp. (65–67).—Am. Jour. Sci., Vol. XLIII, Jan. 1892.

—Native Antimony at Prince William, York Co., N. B. 3 pp. (276–278).—Am. Jour. Sci., Vol. XXX, Oct. 1885.

—The Washington Co., Penn., Meteorite. 1 p.—Am. Jour. Sci., Vol. XXX., Nov. 1885.

—Bohemian Garnets. 9 pp., with map.—Trans. Am. Inst. Min. Eng., Baltimore Meeting, Feb. 1892.

—Mineralogical Notes of Brookite, Octahedrite, Quartz and Ruby. 2 pp. (329–330),—Am. Jour. Sci., Vol. XLIII, April, 1892.

—On the Occurrence of Diamonds in Wisconsin. 2 pp. (638–639).—Bull. Geol. Soc. Am., Vol. II.

—On the Occurrence of Fire Opal in a Basalt in Washington State. 1 p. (639).—Bull. Geol. Soc., Am., Vol. II.

—Exhibition of Gems used as Amulets, etc. 3 pp. (29–31).—Jour. American Folk-Lore.

—On Remarkable Coffer Minerals from Arizona. 4 pp. (275–278), Oct. 5, 1885).

—The North Carolina Diamond. 1 p., Ill.—Am. Jour. Sci., Vol. XXXIV, Dec. 1887.

—A Note on the Finding of Two Fine American Beryls (abstract). 2 pp. (275–276).—Proc. A. A. A. S., Vol. XXXII, Minneapolis meeting, Aug. 1883.

—Rhodocrosite from Colorado. 1 p.—Am. Jour. Sci., Vol. XXXIV, Dec. 1887.

—Hydrophane from Colorado and Silver Nugget from Mexico. 1 p.—Am. Jour., Sci., Vol. XXXIV, Dec. 1887.

—On a Large Garnet from New York Island. 2 pp., Ill.—N. Y. Acad. Sci., May 30, 1886.

—Korean Curios. 2 pp. (172–173), Ill.—Science, Vol. IV, No. 82, Aug. 29, 1884.

—On the Tourmaline and Associated Minerals of Auburn, Maine. Andalusite from Gorham, Maine. The White Garnet from Wakefield, Canada. 4 pp. (1–4), Am. Jour. Sci., Vol. XXVII, April, 1884, 2 copies.

—On a White Garnet from near Hull, Canada. 2 pp. (269–270). (Abs.).—Proc. A. A. A. S., Vol. XXXII, Aug. 1883.

—Topaz and Associated Minerals from Stoneham, Oxford Co., Maine. (Abs.). 3 pp. (271–273).—Proc. A. A. A. S., Vol. XXXII, Aug. 1883.

—Minerals from Fort George, New York City. (Abs.). 1 p.—Trans. N. Y. Acad. Sci., Vol. VII, No. 2, Nov. 1887.

—Andalusite from a New American Locality. 2 pp. (270–271). (Abs.).—Proc. A. A. A. S., Vol. XXXII, Aug. 1883.

—The Gem Collection of the U. S. National Museum. 7 pp. (268–275).—Rep. Smithsonian Inst., 1885–86, Part II.

(AND WEINSCHENK, E.)

—Meteoritenstudien, mit einer Tafel. 11 pp.—Tschermak's Mineralog. u. Petrograph. Mittheilungen, XII Band, 3 Heft, 1891.

LANE, ALFRED C.

—On the Recognition of the Angles of Crystals in Thin Sections. 18 pp. (365–382), 1 pl.—Bull. Geol. Soc. Am., Vol. II, May, 1891.

—On the Estimate of the Optical Angle by Observations in Parallel Light. 6 pp. (53–58).—Am. Jour. Sci., Vol. XXXIX, Jan. 1890.

—Estimate of the Optical Angle; A Correction.—Am. Jour. Sci., Vol. XLIII, Jan. 1892.

—Separat-Abdruck aus den Mineralogische und Petrographischen Mittheilungen, Herausgegeben von G. Tschermak. Über Den Habitus Des Gesteinsbildenden Titanit. 9 pp. (207–215), Ill.

—Petrographical Tables. 3 pp. (341–343), 2 tables.—Am. Geol., June, 1891.

LESQUEREUX, LEO.

—Remarks on Some Fossil Remains Considered as Peculiar Kinds of Marine Plants.—Proc. U. S. Nat. Mus., Vol. XIII, No. 792, 8 pp. (5–12), 1890.

LINDAHL, JOSUA, PH.D.

—Description of a Skull of Megalonyx Leidyi, n. sp. 9 pp., 5 pl.—Read before Am. Philos. Soc., Jan. 2, 1891.

—Our Pennatulid-Slägtet Umbellula, Cuv. 22 pp., 3 pl.—Till Kongl. Vet-Akad. Inlemnad den 10 Febr. 1874.

LEVERETT, FRANK.

—On the Significance of the White Clays of the Ohio Region. 7 pp. (18–24).—Am. Geol., Vol. X, July, 1892.

—The Cincinnati Ice Dam. 1 p.—Proc. A. A. A. S., Vol. XL, 1892.

—Relation of a Loveland, Ohio, Implement-bearing Terrace to the Moraines of the Ice-Sheet. 1 p.—Proc. A. A. A. S., Vol. XL, 1891.

LINTON, EDWIN, PH.D.

—Notes on Entozoa of Marine Fishes of New England, with Descriptions of Several New Species. Part II. 82 pp. (719–900), 15 pl.—Ext. An. Rep. Com. Fish and Fisheries for 1887, 1890.

—Notes on Entozoa of Marine Fishes, with Descriptions of New Species. Part III.—Ext. An. Rep. U. S. Com. Fish and Fisheries, 1888. 20 pp. (523–542), 1891.

—Notes on Entozoa of Marine Fishes of New England, with Descriptions of Several New Species. 46 pp. (453–498), 6 pl.—Ext. An. Rep. Com. Fish and Fisheries for 1886.

—The Anatomy of Thysanocephalum Crispum, Linton, a Parasite of the Tiger Shark. 14 pp. (543–556), 7 pl.—Ext. An. Rep. Com. Fish and Fisheries for 1888.

—Notes on Ovian Entozoa. 27 pp. (87–113), 5 pl.—Proc. U. S. Nat. Mus., Vol. XV, No. 83, 1892.

—Mount Sheridan and the Continental Divide. 27 pp.—Trans. Acad. Sci. and Art of Pittsburgh, delivered March 18, 1892.

—Notes on a Trematode from the White of a Newly-Laid Hen's Egg. 3 pp. (367–369), Ill.—Proc. U. S. Nat. Mus., Feb. 16, 1887.

—On Two Species of Larval Dibothria from the Yellowstone National Park. 15 pp. (65–79), pl., XXIII–XXVII.—Bull. U. S. Fish Com., Vol. IX, for 1889.

—Notice of the Occurrence of Protozoan Parasites (Psorosperms) on Cyprinoid Fishes in Ohio. 3 pp. (359–361), 1 pl.—Bull. U. S. Fish Com., Vol. IX, for 1889.

—On Certain Wart-like Excrescences Occurring on the Short Minnow, Cyprinodon Variegatus, due to Psorosperms. 4 pp. (99–102), 1 pl.—Bull. U. S. Fish Com. for 1889, Vol. IX.

—A Contribution to the Life-History of Dibothrium Cordiceps, a Parasite Infesting the Trout of Yellowstone Lake. 22 pp. (337–358), 2 pl.—Bull. U. S. Fish Com. for 1889, Vol. IX.

LUNDGREN, BERNHARD.

—Öfversigt af Sveriges Mesozoiska Bildningar. 37 pp.—Nr Lunds Universitats Årsskrift, Tom. XXIV, 1888.

MCCALLEY, HENRY, C. and M. E.

—Natural Gas and Petroleum in North Alabama. 14 pp., Ill.—Ala. Ind. and Sci. Soc. Anniston Meeting, April, 1891.

—Geological Survey of Alabama. Report on the Coal Measures of the Plateau Region of Alabama, including a Report on the Coal Measures of Blount County, by A. M. Gibson, with map and two Geol. Sections. 238 pp., 1891.

—North Alabama, or the Mountain, Manufacturing and Mining Region of Alabama. 18 pp.—Birmingham Illustrated, 2 copies.

MCCHARLES, A.

—The Foot-Steps of Time in the Red River Valley, with Special Reference to the Salt Springs and Flowing Wells to be Found in it. 18 pp.—Hist. and Sci. Soc. Manitoba, Trans. No. 27, 1886–87.

MCKELLAR, PETER, F.G.S.

—On Pot-Holes North of Lake Superior Unconnected with Existing Streams. 3 pp. (568–570).—Bull. Geol. Soc. Am., Vol. I.

—The Correlation of the Animikie and Huronian Rocks of Lake Superior. 11 pp. (63–73).—Trans. Roy. Soc. Can., Vol. V, Sec. IV, 1887.

MALLETT, F. R.

—On Recent Coal Explorations in the Darjiling District. 7 pp., 1 pl.—Records of the Geol. Surv. of India, No. 3, 1877.

—On Mysorin and Atacamite from the Nellore District. 6 pp.—Records Geol. Sur. of India, Vol. XII, 1879.

—On the Ferruginous Beds Associated with the Basaltic Rocks of Northeastern Ulster in Relation to Indian Laterite. 8 pp.—Records Geol. Sur. of India, Vol. XIV, Part I, 1881.

—On Cobaltite and Danaite from the Khetri Mines. 6 pp.—Geol. Sur. of India, Vol. XIV, Part II, 1881.

—Geological Notes on Part of Northern Hazaribagh. 12 pp.—Geol. Sur. of India, No. 1, 1874.

—On Some of the Mineral Resources of the Andaman Islands. 6 pp.—Geol. Sur. of India, Vol. XVII, Part II, 1884.

—On Some Forms of Blowing Machines Used by the Smiths of Upper Assam. 3 pp., 3 pl.—Geol. Sur. of India, No. 3. 1877.

—Memoirs of the Geological Survey of India. pp. 129, 4 pl., 1 map, 1869.

—Memoirs of the Geological Survey of India. 28 pp., 2 pl., Vol. III, Part III.

—On the Iron Ores and Subsidiary Materials for the Manufacture of Iron in Northeastern Part of the Jabalpur District. 24 pp., 1 map.—Geol. Sur. of India, Vol. XIII, 1883.

—On Sapphires Recently Discovered in the Northwest Himalaya. 3 pp.—Geol. Sur. of India, Vol. XV, 1882.

—New Faces Observed on Crystals of Stilbite from the Western Ghats, Bombay. 3 pp.—Geol. Sur. of India, Vol. XV, 1882.

MARTIN, DR. K. (and A. WICHMANN).

—Sammlungen des geologischen Reichs-Museums in Leiden. 2 Serie, Band I. 206 pp., 5 pl., 1887–89.

MATTHEW, G. F., M.A., F.R.S.C.

—Sur Le Développement des Premiers Trilobites. 14 pp., Ill.—Extrait des Annales de la Société Royale Malacol. de Belg., Tome XXIII, 1888.

—Eozöon and other Low Organisms in Laurentian Rocks at St. John. 10 pp., Ill.—Reprint Bull. No. 10 Nat. Hist. Soc. N. B. Read Oct. 7, 1890.

—A Preliminary Notice of a New Genus of Silurian Fishes. 5 pp. (69–73), Ill.—Ext. Rep. of Field Meeting, July, 1886. Read Oct. 5, 1886.

—On the Occurrence of Leptoplastus in the Acadian Cambrian Rocks. 5 pp. (485–489), Ill.—The Canadian Record of Science, Oct., 1889, 2 copies.

—On Some Causes which may have Influenced the Spread of the Cambrian Faunas. 15 pp. (255–269).—Canadian Record of Science, Vol. IV, Jan. 1891.

—Tidal Erosion in the Bay of Fundy. 6 pp. (368–373).—The Canadian Naturalist, Vol. IX, No. 6.

—Synopsis of the Fauna in Division I of the St. John Group, with Preliminary Notes on the Higher Faunas of the same Group. 7 pp.—Bull. No. V of the Nat. Hist. Soc. N. B. Read April 6, 1886.

—List of Fossils Found in the Cambrian Rocks in or near St. John, N. B. 12 pp.—Nat. Hist. Soc. Bull. No. 10.

—Protolenus—A New Genus of Cambrian Trilobites, Art. II. 4 pp.—Bull. X Nat. Hist. Soc. N. B., Sept. 1892.

—Note on Leptoplastus. 2 pp. (461–462), Ill.—Canadian Rec. Sci., Dec. 1891.

—Sketch of Charles Frederick Hartt, by Dr. J. C. Branner.—Bull. No. IX Nat. Hist. Soc. N. B. 4 pp., with portrait.

—On Cambrian Organisms in Acadia. 28 pp. (135–162), 5 pl.—Trans. Roy. Soc. Can., Sec. IV, 1889.

—Illustrations of the Fauna of the St. John Group, No. 5. 44 pp. (123–166), 6 pl.—Trans. Roy. Soc. Can., Sec. IV, 1890.

—Illustrations of the Fauna of the St. John Group Continued; on the Conocoryphea, with further remarks on Paradoxoides. 26 pp. (99–124), 1 pl.—Trans. Roy. Soc. Can., Sec. IV, 1884.

—Illustrations of the Fauna of the St. John Group Continued. No. III, Descriptions of New Genera and Species, including a Description of a New Species of Solenopleura, by J. F. Whiteaves. 56 pp. (29–84), 3 pl.—Trans. Roy. Soc. Can., Sec. IV, 1885.

—On the Cambrian Faunas of Cape Breton and New Foundland. 11 pp. (147–157), Ills.—Trans. Roy. Soc. Can., Sec. IV, 1886.

—Illustrations of the Fauna of the St. John Group, No. IV, Part I, Descriptions of a New Species of Paradoxoides (Paradoxoides regina). Part II. The

Smaller Trilobites, with Eyes. Ptychoparidæ and Ellipsocephalidæ. 52 pp. (115–166), 3 pl.—Trans. Roy. Soc. Can., Sec. IV, 1887.

—On Some Remarkable Organisms of the Silurian and Devonian Rocks in Southern New Brunswick. 14 pp. (49–62), 1 pl.—Trans. Roy. Soc. Can., Sec. IV, 1888.

—Illustrations of the Fauna of the St. John Group, No. VI. 33 pp. (33–65), 2 pl.—Trans. Roy. Soc. Can. Sec. IV, 1891.

—Sketch of the Life and Scientific Work of Professor Chas. Fred Hartt, by Richard Rathbun. 26 pp.—Bull. Nat. Hist. N. B., 10 copies.

SPECIMENS.

About forty rocks and ore specimens from F. L. Nason, Franklin Furnace, N. J.

A large collection of fossils from the recent formations in the eastern part of the United States, from Jos. Willcox.

A choice collection of staurolite crystals and other specimens from Dr. Heighway, Fannin Co., Ga.

Sixty-five choice palæontological and mineralogical specimens from W. F. Farrier, Ottawa, Can.

A box of glacial erratics from C. B. Goodspead, Oneida Co., Wis.

A collection of fossils and rocks from Dr. C. L. Gwin, Galveston, Tex.

A choice collection of Devonian fossils from H. Moore, Columbus, O.

A box of fossils and rocks from Rev. J. Davis, Hannibal, Mo.

A number of fossils from L. C. Wooster, Eureka, Kan.

A box of red jasper conglomerates, slickensides and pebbles from F. Leverett.

A collection of fossils from J. W. Beede, Topeka, Kan.

Two large museum specimens from Professor W. H. Beach, Milwaukee, Wis.

Two large and handsome specimens of selenite from J. E. Talmage, Salt Lake City.

(*Further acknowledgments of pamphlets already received will be made in the next issue*).